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Stratigraphy of the Jurassic System in the Wapella-Moosomin Area, Southeastern Saskatchewan

L.K. Kreis

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Abstract

The Triassic/Jurassic section of southeastern Saskatchewan is an unconformity bound sequence between the Mississippian subcrop and the Cretaceous Mannville Formation. It is not readily correlatable with the Jurassic of the type area in the southwestern part of the province mainly because one of the more readily recognizable units, the Lower Member of the Shaunavon Formation (which is critical to stratigraphic division), changes facies from west to east. For this reason, much of the Middle Jurassic section in the southeast has been considered "undifferentiated" prior to this study.

Five hundred geophysical well logs, 1500 m of core and well cuttings from the Wapella-Moosomin area provide the database for a detailed study of the Jurassic stratigraphy, sedimentology and paleontology of this area. The combination of these make an interpretation of the paleo-environments and depositional history feasible.

There are four lithostratigraphic units in the Jurassic of southeastern Saskatchewan: Watrous, Gravelbourg, Red Jacket and Rierdon formations. The Red Jacket, a new formation, is proposed as the lateral facies equivalent to strata lying between the lower member of the Gravelbourg and the Vanguard formations of the type area. The western limit of this unit has been arbitrarily established. A number of discontinuities within the Red Jacket Formation ranging from suspected diastems to an obvious disconformity with a distinct physical expression can be used to divide this formation into formally designated members and informal units. Thus, in ascending order, the Red Jacket Formation is divided into the Rocanville, Moosomin, and the Burrows members. The members are further divided into informal units including: Rocanville "A", "B" and "C", Moosomin "A" and "B", and Burrows "A" and "B". Locally, Moosomin "A" includes subunits Moosomin "A1" and "A2".

The Triassic/Jurassic (?) red beds of the lower member of the Watrous Formation represent the earliest post-Mississippian deposits in the study area. They appear to have been laid down in a restricted marine environment but the sediments were repeatedly exposed and oxidized, as well as reworked. This initial phase was followed by somewhat less restricted marine deposition in Bajocian time, as represented by the sedimentary sequence of the upper member of the Watrous Formation and unit A of the lower member of the Gravelbourg Formation. Unit B of the lower Gravelbourg is overlain by rocks which were deposited in a near-normal marine environment. In contrast, strata belonging to the succeeding Red Jacket Formation indicate a wide spectrum of depositional environments ranging from freshwater to brackish-water (estuarine) and near-normal to normal marine settings. This variation is considered to have been caused by minor yet frequent fluctuations in sea level causing broad shifts in the depositional environments. In addition, there are abrupt changes represented by a number of discontinuities in the Red Jacket Formation which attest to some major disruptive events during Bajocian to Bathonian time. This unstable period was followed by a major marine transgression and the Rierdon shales were laid down in the study area during Late Bathonian to Callovian time.

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Introduction

General Statement

The Jurassic sediments of southeastern Saskatchewan represent a little studied, highly intriguing succession of lithologies including evaporites, sandstones, siltstones, shales and carbonates. Much of the section defies detailed correlation with the type area in southwestern Saskatchewan. Rapid facies changes, numerous discontinuities, and a general lack of consistent stratigraphic markers has earned much of the Middle Jurassic section an undifferentiated status in southeastern Saskatchewan. A redefinition of this part of the Middle Jurassic stratigraphy is proposed as a result of extensive investigations for this report, giving rise to the Red Jacket Formation.

Currently, medium gravity oil is produced from discontinuous, unconsolidated to variably cemented sands of Middle Jurassic age at several stratigraphic intervals in the Wapella and Red Jacket fields of southeastern Saskatchewan. In addition to the Middle Jurassic production in these defined fields there is significant miscellaneous production in the North Wapella and Moosomin localities (Figure 1). Within the Wapella Field there is also commingled production of medium gravity oil from the Mannville Formation of Cretaceous age. Miscellaneous Middle Jurassic production also occurs in a number of isolated wells proximal to the aforementioned locations within the area of study. This area was chosen to include all known occurrences of Middle Jurassic petroleum production in southeastern Saskatchewan.

The oil in the Middle Jurassic and Cretaceous (i.e. Mannville Formation) strata in the study area appears to be Mississippian crude oil which migrated up a fracture-fault system and leaked, bed by bed, up into overlying Mesozoic strata (van Delinder, 1984). Based on the stratigraphic distribution and geochemical composition of this oil it is likely that it came from a source in the Mississippian Madison Group (Brooks *et al.*, 1987).

Study Area

The principal area under investigation extends westward from the Manitoba-Saskatchewan border to Range 2 west of the Second Meridian and northward from Township 12 to 17 inclusive (Figure 1). This area will be referred to as the Wapella-Moosomin area throughout the report. In addition, Jurassic strata between the type area in southwestern Saskatchewan and the Wapella-Moosomin area were carefully traced in order to establish stratigraphic relationships across all of southern Saskatchewan.

Scope and Method of Study

Exploration and development of oil-prone sediments of Middle Jurassic age in southeastern Saskatchewan has been hampered by a lack of understanding of the stratigraphic and sedimentological intricacies inherent to much of the Middle Jurassic sequence in the area.

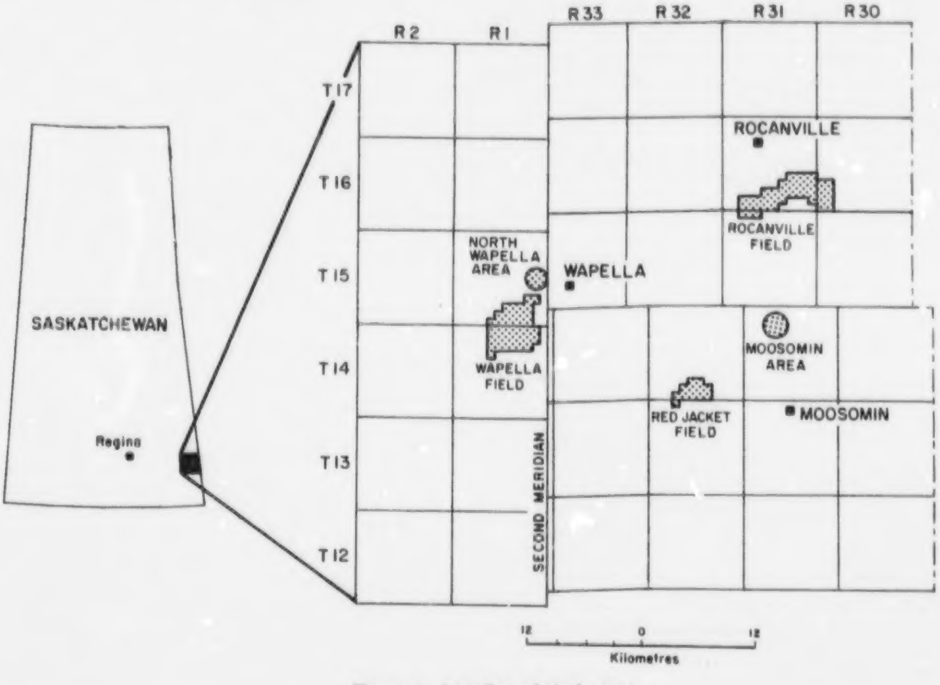


Figure 1 - Location of study area.

Therefore, in the main focus of the study, two primary objectives were pursued:

1) To establish the stratigraphic relationship between the Jurassic section in the Wapella-Moosomin area and that in the type area in southwestern Saskatchewan.

2) To provide an interpretation of the depositional history and the paleo-environments of the Jurassic sequence in the area of study, particularly with respect to the oil-prone Middle Jurassic Red Jacket Formation proposed in this report.

This study is based on data from some 500 wells penetrating Jurassic strata in the Wapella-Moosomin area. Geophysical well logs, borehole sample cuttings, and some 1500 m of core representing various portions of the Jurassic section were examined. Unfortunately, cores commonly only cover short stratigraphic intervals (normally less than 15 m) and are severely restricted in their geographic distribution. The majority of cores are located in and around the Wapella Field and, to a lesser extent, in the Red Jacket Field and Moosomin area. This lack of core in the stratigraphic as well as the geographic sense has proven to be a significant limiting factor to the understanding of the regional stratigraphic relationships. In addition, many of the cores are of poor quality making sedimentological interpretations difficult.

The relative abundance of cores and wells within and around the Wapella Field has provided much of the author's understanding of the stratigraphic relationships and sedimentological interpretations of the strata studied. Paleontological, palynological and ichnological aspects of the Jurassic rocks have also been taken into account to solve stratigraphic problems and attempt paleo-environmental reconstructions.

All well data are shown in metric units, that is, depths and thicknesses are recorded in metres, and distances shown in kilometres. Colour designation used for lithological description follows the chart issued by the Geological Society of America (second printing, 1951). The grading scale for grain size of sandstone is based on the Wentworth scale as shown by Folk (1968), while the sorting classification follows the recommendations of Payne (1942) (See Appendix C.1).

Well data, including the location of the wells used in the study (i.e. all wells drilled in Wapella-Moosomin area up to December, 1990), geophysical log picks of tops of pertinent stratigraphic units in relation to Kelly Bushing (K.B.), and all cored intervals through Jurassic strata in the Wapella-Moosomin area, are tabulated in Appendix A. Photographs showing a selection of pertinent sedimentological and paleontological features are shown in Appendix B. Appendix C contains core descriptions from five wells showing the most characteristic features singled out for discussion throughout the report.

Geological Setting

Jurassic strata of the study area were deposited on the east flank of an intracratonic depression traditionally referred to as the Williston Basin (Figure 2). Kent (1987) suggested that this basin was an actively subsiding structure during much of the Phanerozoic, with the greatest paleobathymetric control on sedimentation occurring during Silurian, Mississippian and Jurassic time.

Christopher (1984) describes an area of uplift in the form of a south-trending ridge of subcropping Mississippian strata along Longitude 102° W which runs directly through the study area (Figure 3). This ridge separates the lower Watrous sub-basin in Saskatchewan from the lower Amaranth sub-basin in Manitoba and is coincident with the Nelson River gravity trend and Birdtail-Waskada Axis (Figure 2). A more detailed discussion of these, and related features of the Williston Basin, will be given in a summary of paleotectonic controls on sedimentation in a later section.

Four mappable Jurassic units are recognized in the Wapella-Moosomin area. They are, in ascending order, the Watrous, Gravelbourg, Red Jacket (introduced in this paper), and Rierdon formations. All of these units are present only in the subsurface. The red beds of the lower member of the Watrous Formation are the oldest strata studied and are believed to be Triassic to possibly Early or Middle Jurassic in age. These red beds appear to have been laid down on a long broad shelf which extended from southern Saskatchewan to as far south as

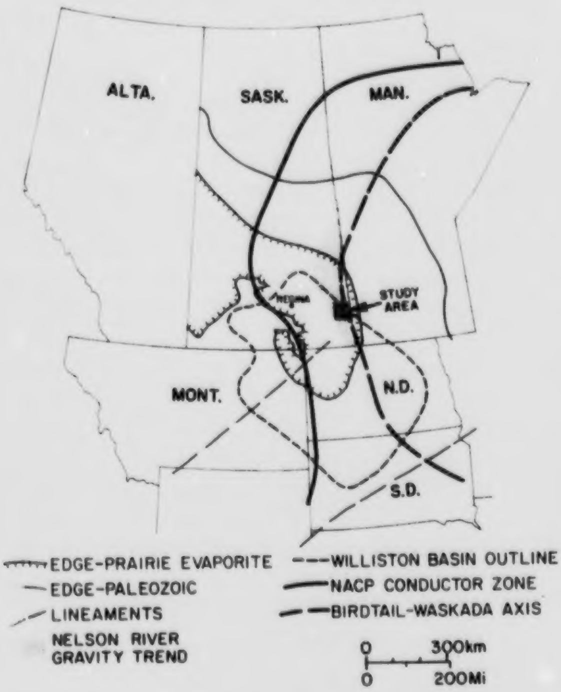


Figure 2 - Major features of the Williston Basin. Modified after Kent (1987, Fig. 10).

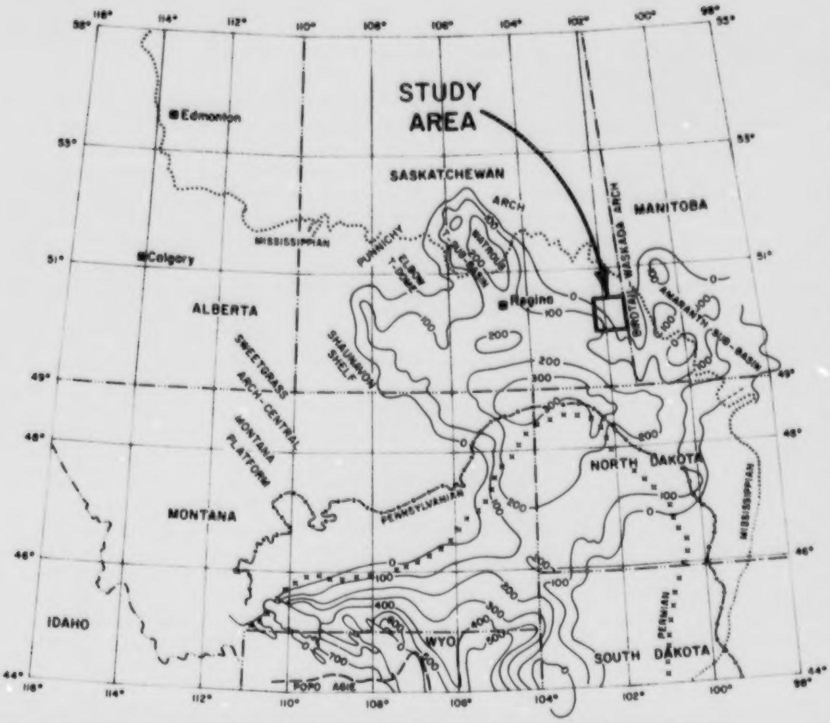

STUDY AREA
Edmonton
Calgary
Regina
ALBERTA
SASKATCHEWAN
MANITOBA
MONTANA
IDAHO
NORTH DAKOTA
SOUTH DAKOTA
WYO
SASKATCHEWAN ARCH
MISSISSIPPIAN
PUNNICHY
WATROUS
SWEETGRASS ARCH–CENTRAL MONTANA PLATFORM
SHAUNAVON SHELF
PENNSYLVANIAN
PERMIAN
MISSISSIPPIAN
BIRDTAIL-WASKADA ARCH
AMARANTH SUB-BASIN
POPO AGIE
0
100
200
300
400
500

Figure 3 - Isopach map showing distribution of Triassic-Jurassic Spearfish and lower Watrous/Amaranth strata in the Williston Basin. Contours are in feet. Modified after Christopher (1984, Fig. 4).

northern Arizona (MacLachlan, 1972). In the study area, the overlying Jurassic strata range in age from Bajocian to Callovian. These sediments are dominantly marine and were deposited in an embayment that spread eastward from the Pacific Coast region across the northernmost part of the United States and adjoining parts of Canada (Imlay, 1980). The study area is located near the northeastern erosional limit of the Jurassic sequences in the Williston Basin (Figure 4a in pocket).

All Jurassic strata in southeastern Saskatchewan, that succeed the lower member of the Gravelbourg Formation, are commonly listed as undifferentiated (Figure 5), and are the focus of this study. They also happen to be oil-prone, and hence, of considerable economic interest. Particular scrutiny is given to the Middle Jurassic

SASKATCHEWAN		SASKATCHEWAN		SASKATCHEWAN		MONTANA, WESTERN AND CENTRAL SASKATCHEWAN		EASTERN SASKATCHEWAN, MANITOBA AND NORTH DAKOTA		SOUTHWEST SASKATCHEWAN		SOUTHEAST SASKATCHEWAN	SOUTHWESTERN SASKATCHEWAN		SOUTHEAST SASKATCHEWAN		SOUTHEAST SASKATCHEWAN	
VIGRASS 1952		SASKATCHEWAN GEOLOGICAL SOCIETY 1952		MILNER AND THOMAS 1954		FRANCIS 1956		FRANCIS 1956		CHRISTOPHER 1984		CHRISTOPHER 1984	IMLAY 1980		KREIS 1988		THIS REPORT 1990	
UPPER SUNDANCE	U-1	J-1	A	VANGUARD	Upper	MORRISON		MORRISON		VANGUARD		JURASSIC (UNDIFFERENTIATED)	MORRISON					
						SWIFT	Upper	SUNDANCE					MASEFIELD		SUCCESS $_1$		SUCCESS $_1$	
															MASEFIELD		MASEFIELD	
	U-2		B		Middle		Middle											
	U-3		C		Lower		Lower											
						RIERDON							RIERDON		RIERDON		RIERDON	
LOWER SUNDANCE	L-1	J-2	A	SHAUNAVON	Upper	PIPER	Upper			SHAUNAVON	Upper		SHAUNAVON	Upper	RED JACKET	BURROWS	RED JACKET	BURROWS
																MOOSOMIN		MOOSOMIN
	L-2		B		Lower		Middle				Lower			Lower		ROCANVILLE		ROCANVILLE
	L-3	J-3		GRAVELBOURG			Lower			GRAVELBOURG	Upper		GRAVELBOURG	Upper				
															LOWER GRAVELBOURG		LOWER GRAVELBOURG	
GYPSUM SPRING	G-1	J-4	A			GYPSUM SPRING	Upper	GYPSUM SPRING	Upper		Lower	LOWER GRAVELBOURG		Lower				
	G-2		B	WATROUS			Lower		Lower	UPPER WATROUS		UPPER WATROUS	UPPER WATROUS		UPPER WATROUS		UPPER WATROUS	
						RED BEDS		RED BEDS		LOWER WATROUS		LOWER WATROUS	LOWER WATROUS		LOWER WATROUS		LOWER WATROUS	

Figure 5 - Historical development of Jurassic nomenclature in Saskatchewan. Formation names shown are accredited to their authors at the top of each column. However, the correlations implied are the interpretation of the present writer based on a comprehensive literature study. The chart does not contain any reference to geologic time nor unconformities. The 1952 Saskatchewan Geological Society scheme is from Francis (1956).

(Bajocian-Bathonian) sediments of the Wapella-Moosomin area that are equivalent to the Shaunavon and the uppermost portion of the Gravelbourg Formation of southwestern Saskatchewan. It is proposed that this "undifferentiated" interval in southeast Saskatchewan be named the Red Jacket Formation with the formal stratigraphic scheme and nomenclature to be discussed in a later section. The west-east cross-section in Figure 4b (in pocket) shows the correlation of Jurassic strata between the type area in southwestern Saskatchewan and the study area in the southeast. The cross-hatched area in Figure 4a (in pocket) illustrates the geographical region in which the Red Jacket Formation is recognizable.

In the Wapella-Moosomin area, Triassic-Jurassic rocks rest with marked angular unconformity upon the subcropping Lower Mississippian Souris Valley Beds (Figure 6). In general, the overlap of younger strata over older ones is in a northeasterly direction. The lower Watrous is overlapped by the upper Watrous, the upper Watrous by unit B of the lower Gravelbourg, and in the extreme northeastern quadrant of the Wapella-Moosomin area, unit B of the lower Gravelbourg is itself overstepped by strata forming the base of the Red Jacket Formation (i.e. the Rocanville Member) (Figure 7, in pocket). The overlying Moosomin and Burrows members and the Rierdon Formation were once present throughout the area but were locally removed by Late Jurassic to Early Cretaceous erosion.

The Early Cretaceous Mannville Formation unconformably overlies distinctly incised Jurassic strata throughout the Wapella-Moosomin area. Removal of Jurassic strata was greatest in the northeastern, northwestern and west-central parts of the area, as indicated by the zero-isopach on the Rierdon Shale map (Figure 8, in pocket) - the youngest Jurassic unit present in this region. Not only is all of the Rierdon Formation absent beyond the zero-edge, but also the uppermost portions of the Red Jacket Formation.

During most of the Jurassic the Wapella-Moosmin area was part of a marine shelf along the northeastern margin of the Williston Basin. The Jurassic strata form a monocline which is concordant to slightly disconcordant with respect to the erosion surface of the underlying Mississippian. A shale marker (i.e. Burrows "A" of Burrows Member of the Red Jacket Formation) within the Jurassic strata dips gently southwest at approximately 4.0 m/km (Figure 9, in pocket), whereas the underlying Mississippian subcrop forms a monocline which dips southwest at approximately 5.0 m/km (Figure 10, in pocket). The present-day structural configuration of the Williston Basin is largely the result of Laramide tectonics (Christopher *et al.*, 1971).

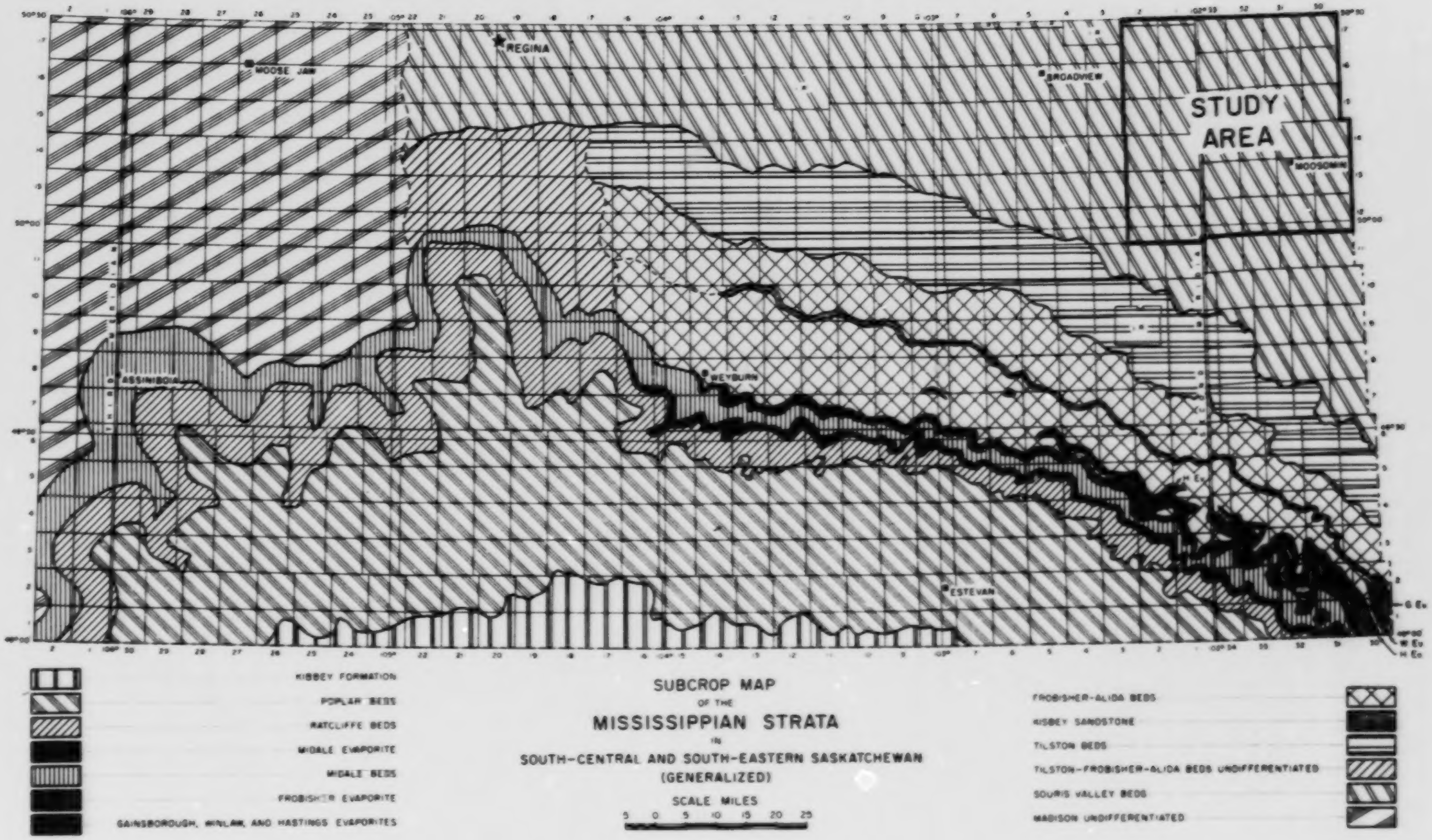

STUDY AREA
REGINA
MOOSE JAW
BROADVIEW
MOOSOMIN
ASSINIBOIA
WEYBURN
ESTEVAN
G. Ev.
W. Ev.
H. Ev.
KIBBEY FORMATION
POPLAR BEDS
RATCLIFFE BEDS
MIDALE EVAPORITE
MIDALE BEDS
FROBISHER EVAPORITE
GAINSBOROUGH, WINLAW, AND HASTINGS EVAPORITES
SUBCROP MAP
OF THE
MISSISSIPPIAN STRATA
IN
SOUTH-CENTRAL AND SOUTH-EASTERN SASKATCHEWAN
(GENERALIZED)
SCALE MILES
5 0 5 10 15 20 25
FROBISHER-ALIDA BEDS
KISBEY SANDSTONE
TILSTON BEDS
TILSTON-FROBISHER-ALIDA BEDS UNDIFFERENTIATED
SOURIS VALLEY BEDS
MADISON UNDIFFERENTIATED

Figure 6 - Map showing study area in relation to the Mississippian subcrop. After Fuzesy (1960, Fig. 3).

Nomenclature and Previous Work

Development of the Stratigraphic Nomenclature

There is limited literature describing the Jurassic rocks of the Wapella-Moosomin area. There are, however, numerous regional and detailed studies and overall reviews of Jurassic stratigraphy and nomenclature which provide an excellent coverage of the Jurassic in the entire Williston Basin. Some of the earliest work includes that of Imlay (1945, 1947 and 1948), Cobban (1945), Hadley and Milner (1953), Schmitt (1953), Towse (1954), Milner and Thomas (1954), Nordquist (1955), and Francis (1956).

One of the earliest detailed studies of Jurassic rocks in Saskatchewan was by Vigrass (1952), who attempted to correlate the known subsurface Jurassic strata of Saskatchewan with some of the type and reference Jurassic sections exposed in the Black Hills area of South Dakota and Wyoming. In the same year, nomenclature using letters and numbers was proposed by the Jurassic Nomenclature Committee of the Saskatchewan Geological Society (see Francis, 1956) to designate mappable Jurassic subsurface units in the province. It is commonly referred to as the "J" (Jurassic) classification in the literature (see Figure 5). This classification was introduced as a temporary measure only, to be used until adequately cored sections and more information were available to relate the Jurassic rocks of Saskatchewan (exclusively in the subsurface) to type sections in the United States (mainly surface exposures).

Milner and Thomas (1954), however, concluded that the great distance between the Jurassic section in the Saskatchewan subsurface and the selected outcrop sections of Montana and South Dakota, coupled with the much thicker development of marine Jurassic strata in Saskatchewan, made correlation with United States sections highly speculative. It was for these reasons that they named the four major lithologic units of the "J" classification and gave them formal, formational status. These four formations are, in ascending order: the Watrous, Gravelbourg, Shaunavon, and Vanguard (Figure 5). The type section for the Watrous Formation is found in the Tidewater Davidson Crown No. 1 well (Lsd. 13-4-27-28W2). Both the Gravelbourg and Shaunavon formations have their type section in the Tidewater Eastend Crown No. 1 well (Lsd. 15-11-6-20W3). The Vanguard Formation was divided into Lower, Middle and Upper members. The type section for each of the members were defined in different wells; the Lower Vanguard was defined in the Tidewater Rush Lake Crown No. 1 well (Lsd. 13-5-18-10W3); the Middle Vanguard in the Tidewater Kelstern No. 1 well (5-27-15-6W3); and the Upper Vanguard in the Sohio-McCarty Coleman Hillandale No. 1 well (Lsd. 4-11-5-14W3).

Undoubtedly, the work of Francis (1956) "Jurassic Stratigraphy of the Williston Basin Area", includes the most comprehensive discussion of Jurassic stratigraphy, nomenclature problems, and development of the stratigraphic scheme up to that time. He conceived and introduced a scheme of five formations representing all rocks of known Jurassic age in the western half of the Williston Basin. Namely, from oldest to youngest, the Gypsum Spring, Piper, Rierdon, Swift and Morrison formations (Figure 5). He termed the red silty shales which underlie these formations the Jura-Triassic Red Beds. Facies changes within the Swift, Rierdon and Piper sequences in the eastern half of the Williston Basin prompted Francis (1956) to invoke an arbitrary cut-off line through the central portion of the basin thereby delineating the area in which these formations are recognizable. East of this line the Swift, Rierdon and Piper formations were combined to become the Sundance Formation, a name that is still widely used in Montana and North Dakota, but rarely or no longer applied in southeastern Saskatchewan or southwestern Manitoba.

Subsequent work by Francis (1957), Peterson (1957), Milner and Blakslee (1958) Klingspor (1958), Springer *et al.*, (1964) and Carlson (1968) present valuable contributions to the discussion of regional Jurassic stratigraphy in the Williston Basin. The most recent contributions are by Peterson (1972), Imlay (1980), Christopher (1984) and Poulton (1984).

Stott (1955) published the first and, so far, the only detailed report on the Jurassic stratigraphy of southwestern Manitoba. He introduced and described four Jurassic formations, from oldest to youngest the Amaranth, Reston, Melita and Waskada formations.

The nomenclature introduced by Milner and Thomas (1954) is currently the most widely used terminology for southwestern and south central Saskatchewan. However, Nordquist (1955), Francis (1956), Milner and Blakslee (1958), Klingspor (1958) and Kreis (1988) all emphasized that facies changes in the Jurassic from west to east make correlation between the type area in southwestern Saskatchewan and southeastern Saskatchewan rather tenuous. To carry such formations as the Shaunavon and Gravelbourg from the southwest across major facies boundaries into southeastern Saskatchewan, is not good stratigraphic practise in an academic (North American Stratigraphic Code 1983, Article 23b) or practical sense.

Since most of the southwestern Saskatchewan terminology cannot be employed in the southeast, the introduction of an arbitrary cut-off is proposed to clearly separate the stratigraphic units of the two areas. This line and the eastern area are emphasized in Figures 4a and 4b (in pocket). The Red Jacket Formation is the name introduced for the combined strata equivalent to the Shaunavon Formation and the upper member of the Gravelbourg Formation in southeastern Saskatchewan (Kreis, 1988). This procedure it is hoped, will resolve the nomenclature problems and thus alleviate some of the stratigraphic challenges.

Previous Work in Study Area

Supplementary to the regional Jurassic publications listed in the previous section are a few studies that discuss, in varying degrees of detail, some aspects of the geology within or conterminous to the study area. For example, Hutt and Schmid (1964) discuss five zones of production in the Jurassic and Cretaceous sequences within the Wapella Field. Morningstar (1984) discusses the hydrocarbon potential and stratigraphic problems of the Jurassic-Cretaceous sequences in southwestern Manitoba - a region conterminous with the present study area.

Wall (1960) and Brooke and Braun (1972) used microfossils to correlate various Jurassic units of the subsurface of Saskatchewan with conterminous areas and outcrop sections. In addition, the latter authors proposed a biostratigraphic scheme applicable to most western interior regions of North America. These workers also discussed the stratigraphic problems encountered in attempting to correlate the present study area and the type Jurassic in southwestern Saskatchewan. Paterson (1968) described Jurassic megafossils from an area in and around the Wapella Field in southeastern Saskatchewan, and introduced an informal stratigraphic break-down for the Jurassic section in that vicinity.

Christopher (1961) added substantially to the understanding of potential tectonic controls in the study area.

The Standard Stratigraphic Framework

The standard Jurassic sequence of southwestern Saskatchewan is discussed in detail in order to show how different it is from the Jurassic sequence in the southeast and to emphasize the difficulties in correlation.

The Underlying Mississippian Surface

Throughout the Wapella-Moosomin area the Lower Mississippian Souris Valley Beds form the subcrop and are composed essentially of fossiliferous, cherty, and variably argillaceous limestone (Figure 6). Paleotopographic relief on the Mississippian erosion surface is a recognizable feature in the northeastern portion of the Williston Basin. Martin (1964), for instance, cited the draping effect of overlying Jurassic strata over "buried hills" of the Mississippian erosional surface as an important criteria used in their recognition.

As noted previously (page 2), a south-trending ridge of subcropping Mississippian strata along longitude 102° W appears to separate the lower Watrous sub-basin of southeastern Saskatchewan from the Amaranth sub-basin in southwestern Manitoba. Christopher (1984 p.87), further suggested that the distribution of lower Watrous sediments is not simply a case of infilling of the underlying eroded Mississippian topography but is largely a result of "...an overprinted static structural control". Apparently, the ridge was a paleotopographic barrier at the time of lower Watrous/Amaranth deposition. This concept is further supported by the near coincidence of the depositional edges and zero limits for the lower and upper members of the Watrous, and units A and B of the lower member of the Gravelbourg, as shown in Figure 7 (in pocket). This coincidence suggests that these units pinch out against a paleotopographically positive Mississippian high that is probably the result of structural movement as well as erosion.

The Watrous Formation

Although never formally defined, common usage divides the Watrous Formation into an upper and lower member - a practice followed throughout the report. The sediments of the lower member of the Watrous are commonly referred to as the "Lower Watrous red beds" in the literature and are generally considered Triassic in age. Strata belonging to the upper member of the Watrous Formation comprise the oldest known Jurassic sediments in Saskatchewan (i.e. Bajocian).

Watrous Formation - Lower Member

Lithology

The lower Watrous rock sequence is composed of highly oxidized, moderately reddish-brown to dark reddish-brown, dolomitic to anhydritic siltstone and mudstone, with rare lenses of poorly sorted, fine- to medium-grained quartzose sandstone near the base. The quartz grains are generally pitted and frosted and commonly found "floating" in a finer-grained matrix.

Paleontology

Palynological evidence suggests that the lower Watrous sediments were deposited in a marginal marine environment which Pocock (1972) interpreted to be proximal to a dry coastline backed by extensive desert.

Member Boundaries

The basal contact of the lower Watrous is readily recognized on geophysical well logs, in core, and in chip samples. On well logs it is marked by a sharp contrast between the high gamma ray signature of the lower Watrous, and the lower gamma ray signature of the underlying Mississippian carbonates (Figure 11, in pocket). In places there may be a distortion in the logs caused by a weathered zone in the uppermost Mississippian strata. This boundary zone is commonly fractured and infilled with chert, anhydrite and gypsum.

The upper contact of the lower Watrous is also marked by a contrast in gamma ray signatures, as the immediately overlying upper Watrous consists of anhydrite, dolomite, and more poorly radioactive shales (Figure 11, in pocket). Some authors describe the upper contact to be sharp while other authors consider it to be gradational. In the study area, the contact appears to be sharp.

In core and in cuttings, the reddish-brown mudstones, siltstones, and minor sandstones in the lower Watrous are easily distinguished from the lithologies of the overlying upper Watrous and underlying Mississippian subcrop.

Thickness and Distribution

Regionally, the lower Watrous (lower Amaranth in Manitoba) covers a large portion of the Williston Basin (Figure 3). In the Wapella-Moosomin area, the lower Watrous forms a wedge-shaped body which thickens to over 30 m in a southwesterly direction (Figures 11, 12 and 13, in pocket). The zero limit occurs in the southwest of this area (Figure 13, in pocket). The close spacing of the 0 to 15 metre contours perhaps indicates some erosional truncation of this unit, or alternatively, may indicate onlap against a steeply sloping, paleotopographically positive Mississippian subcrop as postulated earlier.

Age and Correlation

Although the lower Watrous member is commonly correlated with the Triassic Spearfish Formation of North Dakota and Montana, and with the lower Amaranth of southwestern Manitoba (Figure 14), its age remains controversial. No fossil remains have been found other than spores (Pocock, 1972) which have been inconclusive in determining its age. The lower Watrous and its equivalent in North Dakota, the upper Spearfish, are widely considered to be either Early Triassic (Goldsmith, 1959; Rascoe and Baars, 1972) or Early Jurassic (Pocock, 1972; Barchyn, 1982). Some authors compromise and combine it as Triassic-Jurassic, suggesting, furthermore, that it may be punctuated by one or more unconformities (Zieglar, 1955; Francis, 1956; Dow, 1967).

In the absence of definitive paleontological data, the assignment of an unequivocal age to the lower Watrous cannot be made. In this study, a compromise is followed considering the lower Watrous to be largely Early Triassic in age but with an undefined portion of the uppermost lower Watrous possibly being of an unknown Early Jurassic age (Figure 14).

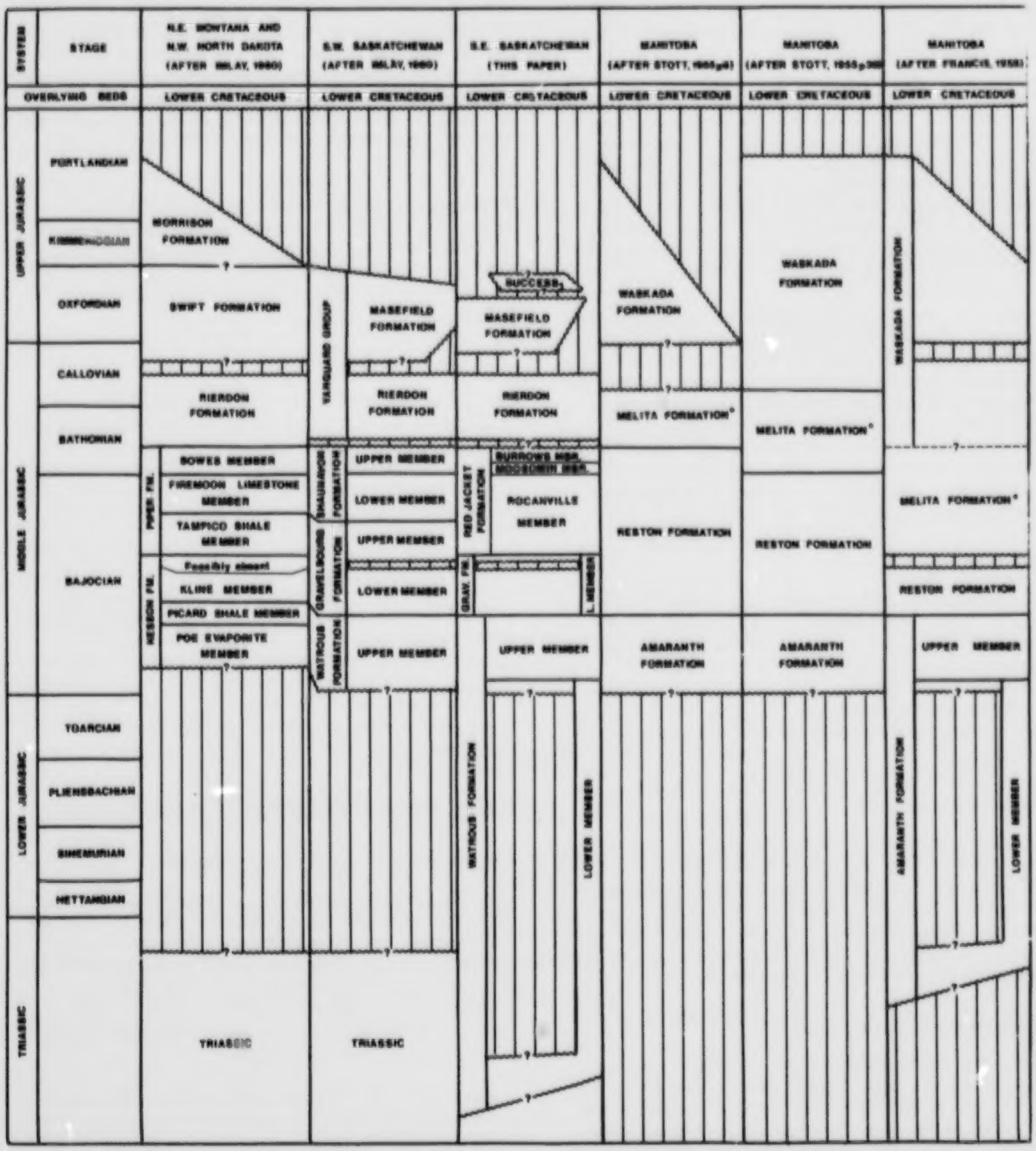

SYSTEM
STAGE
N.E. MONTANA AND N.W. NORTH DAKOTA (AFTER IMLAY, 1980)
S.W. SASKATCHEWAN (AFTER IMLAY, 1980)
S.E. SASKATCHEWAN (THIS PAPER)
MANITOBA (AFTER STOTT, 1955,p8)
MANITOBA (AFTER STOTT, 1955,p36)
MANITOBA (AFTER FRANCIS, 1956)
OVERLYING BEDS
LOWER CRETACEOUS
UPPER JURASSIC
MIDDLE JURASSIC
LOWER JURASSIC
TRIASSIC
PORTLANDIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BATHONIAN
BAJOCIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
MORRISON FORMATION
SWIFT FORMATION
RIERDON FORMATION
PIPER FM.
BOWES MEMBER
FIREMOON LIMESTONE MEMBER
TAMPICO SHALE MEMBER
Possibly absent
NESSON FM.
KLINE MEMBER
PICARD SHALE MEMBER
POE EVAPORITE MEMBER
TRIASSIC
VANGUARD GROUP
MASEFIELD FORMATION
RIERDON FORMATION
SHAUNAVON FORMATION
UPPER MEMBER
LOWER MEMBER
GRAVELBOURG FORMATION
UPPER MEMBER
LOWER MEMBER
WATROUS FORMATION
UPPER MEMBER
TRIASSIC
SUCCESS
MASEFIELD FORMATION
RIERDON FORMATION
RED JACKET FORMATION
BURROWS MBR.
MOOSOMIN MBR.
ROCANVILLE MEMBER
GRAV. FM.
L. MEMBER
UPPER MEMBER
WATROUS FORMATION
LOWER MEMBER
WASKADA FORMATION
MELITA FORMATION*
RESTON FORMATION
AMARANTH FORMATION
WASKADA FORMATION
MELITA FORMATION*
RESTON FORMATION
AMARANTH FORMATION
WASKADA FORMATION
MELITA FORMATION*
RESTON FORMATION
AMARANTH FORMATION
UPPER MEMBER
LOWER MEMBER
?

Figure 14 - Stratigraphic correlation chart of Jurassic units in southeastern Saskatchewan and adjacent areas.

Watrous Formation - Upper Member

Lithology

The dominant lithologies of the upper member of the Watrous Formation are dolomite, anhydrite, and dolomitic mudstone. Generally, the anhydrite occurs as light bluish-grey to medium bluish-grey nodules in a very pale orange to greyish-orange dolomitic matrix. The interbeds of dolomitic mudstone tend to be olive-black to greenish-black, and may also contain anhydrite nodules. The anhydrite nodules commonly coalesce to form a "chickenwire" texture.

Rare occurrences of thin quartzose sandstone beds are recognized in drill cuttings and on geophysical logs in the upper quarter of the upper Watrous sequence in southeastern Saskatchewan. Very fine- to fine-grained, clear quartz also occurs locally in minor amounts as scattered floating grains in a dolomite matrix in this area. Beyond the northeastern limit of unit A of the lower Gravelbourg the upper Watrous was exposed and unit B of the lower Gravelbourg disconformably overlies the upper Watrous (Figures 4b, 7, 11, 12, and 15, in pocket). Below this disconformity, the upper Watrous section is distinctly brecciated and shows fractures infilled by secondary gypsum. This brecciation is well illustrated in core in Tricent *et al.* Moosomin 4-28-14-31 (Figure 16). A physico-chemical process involving repeated hydration/dehydration of the anhydrite in the upper Watrous at the unconformity surface during alternating periods of submergence and exposure is envisaged as a possible cause of the brecciation in this unit (Christopher, pers. comm., 1988).

Paleontology

No megafossils have been reported so far from the upper Watrous, but palynological investigations by Pocock (1972) identified sixteen terrestrial and four marine palynomorph species. The presence of microplanktonic species such as *Evittia waltonii* and *Leiosphaeridia hyalina* (Defl.) n. comb. led him to assign a marine depositional environment to the upper Watrous.

Member Boundaries

As noted earlier, the boundary between the upper and lower Watrous is marked by a sharp contrast in gamma ray signature. The top of the upper Watrous is commonly chosen at the last occurrence of anhydrite (Milner and Thomas, 1954), and appears to be in gradational contact with the overlying dolomitic limestones of the lower member of the Gravelbourg Formation.

Thickness and Distribution

The upper Watrous extends beyond the study area and well into southwestern Saskatchewan (Figures 4a, 4b and 11, in pocket). There is a marked increase in the thickness of the upper Watrous evaporitic sequence, however, east of the Hope Imperial Yellow Grass 16-26-9-16 well (Lsd. 16-26-9-16W2), as distinctly expressed in Figure 4b (in pocket). It appears that the evaporitic upper Watrous increases in thickness at the expense of the overlying lower member of the Gravelbourg Formation in the direction of the Wapella-Moosomin area (Figures 4a and 4b, in pocket).

In the Wapella-Moosomin region, the upper Watrous forms a wedge-shaped body which thickens from a zero edge in the northeast quadrant, to more than 40 m in the southwest (Figure 17, in pocket). It oversteps the underlying lower Watrous in a northeasterly direction (Figure 13, in pocket) and rests unconformably upon the Mississippian Souris Valley Beds. Milner and Thomas (1954) recorded a similar overstepping relationship in southwestern Saskatchewan. A prominent dolomite bed near the base of the upper Watrous disappears in the direction of the study area giving stratigraphic evidence that the upper Watrous onlaps the Mississippian subcrop.

Attenuation of the upper Watrous in the Wapella-Moosomin area is not entirely depositional, but can also be attributed to erosion below the disconformity that marks the base of unit B of the lower member of the Gravelbourg Formation (Figures 4b, 11, 12 and 15, in pocket).

Age and Correlation

The upper Watrous is generally considered to be of Bajocian age and correlated with the Poe Evaporite and overlying Picard Shale members of the Nesson Formation of northeastern Montana and northwestern North Dakota (Imlay, 1980), and the lower Amaranth of Manitoba (Figure 14).

The Gravelbourg Formation

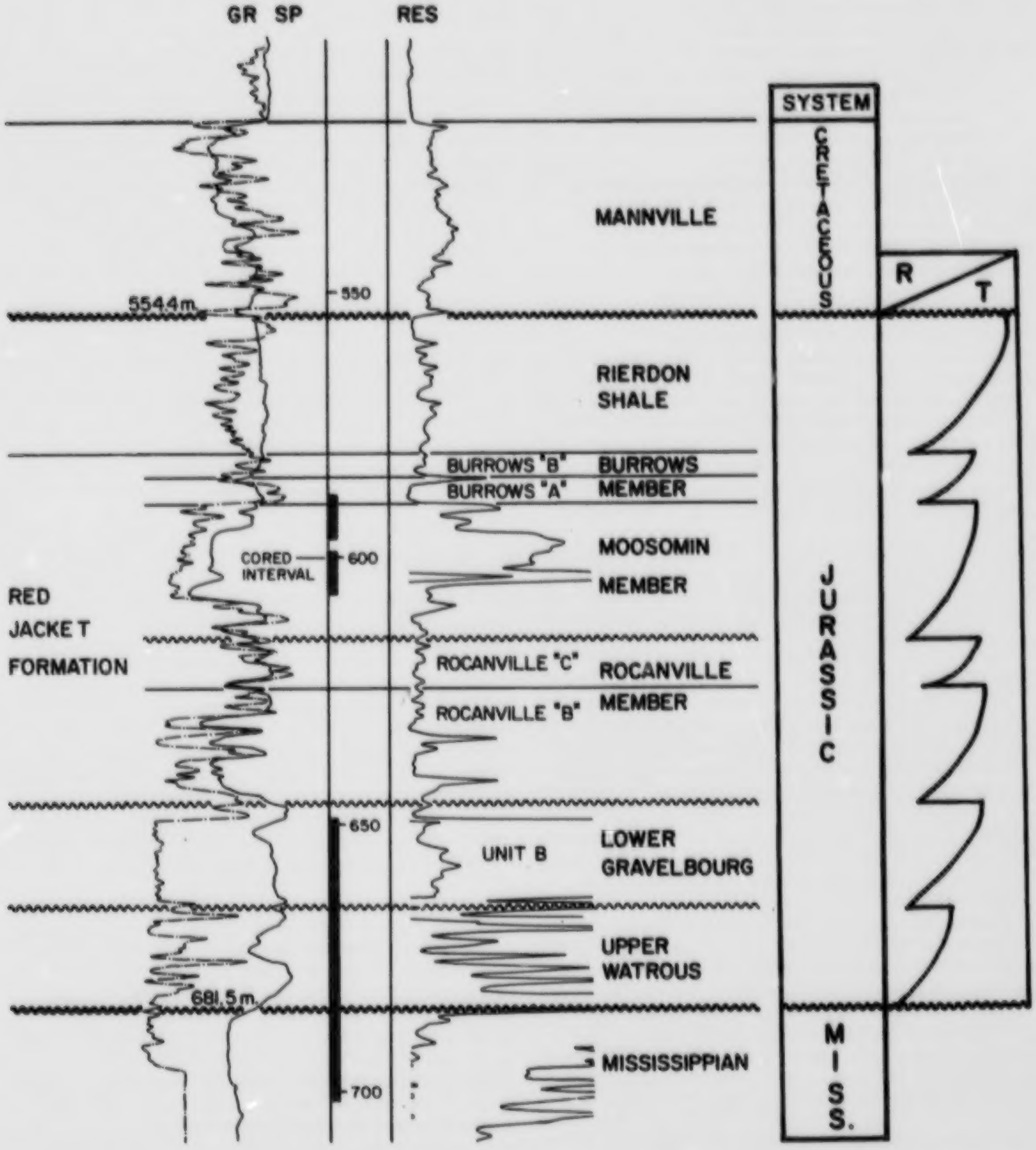
Like the Watrous, the Gravelbourg Formation has been informally divided into upper and lower members, which have become entrenched in the literature through common usage without formal introduction. This informal division is adopted in this report. A further division of the lower Gravelbourg into units A and B is also proposed in this work.

Gravelbourg Formation - Lower Member

Lithology

Unit A is generally a pale yellowish-brown to light-olive grey, dolomitic, variably argillaceous limestone. Locally, the limestone has algal laminations, and/or is partially oolitic. In places, it contains interbeds of greenish-grey to variegated, dolomitic mudstone. Fine-grained, quartzose sandstone and scattered grains of clear quartz in the limestone are a minor constituent of this unit in southeastern Saskatchewan.

A zone of weathered dolomitic limestone with angular to well-rounded inclusions of medium bluish-grey to white chalcedonic chert, reaching pebble size (Photo 1), is commonly found at or near the top of unit A in both southwestern and southeastern Saskatchewan. It defines the disconformable contact between units A and



TRICENT ET AL MOOSOMIN 4-28-14-31
(Lsd. 4-28-14-31W1)

KB: 556.0 m.

GR SP
RES
SYSTEM
CRETACEOUS
MANNVILLE
550
554.4m.
R
T
RIERDON
SHALE
BURROWS "B"
BURROWS "A"
BURROWS
MEMBER
CORED INTERVAL
600
MOOSOMIN
MEMBER
RED
JACKET
FORMATION
ROCANVILLE "C"
ROCANVILLE "B"
ROCANVILLE
MEMBER
JURASSIC
650
UNIT B
LOWER
GRAVELBOURG
UPPER
WATROUS
681.5 m.
MISSISSIPPIAN
700
MISS.

Figure 16 - Tricent *et al.* Moosomin 4-28-14-31 well showing cored intervals. This diagram also shows an interpretation of the occurrence of transgressions (T) and regressions (R) in the Jurassic stratigraphic succession. Note that Rocanville "A" of the Rocanville Member is not present.

B of the lower Gravelbourg. Commonly, this zone is vuggy and contains euhedral, bipyramidal secondary quartz crystals up to 2 mm in length.

Unit B is characterized by interbedded light olive-grey to very light-grey, weakly dolomitic, argillaceous, glauconitic, and bioclastic limestone and olive-grey calcareous mudstone. The limestone is commonly quite sandy, composed of quartz grains (up to 50 percent), chalcedonic chert, and bioclastic, peloidal, oolitic and algal material. These sandy limestones commonly contain partially pyritized fossil fragments (mainly of pelecypods), peloids and ooids at or near the upper contact with the overlying Rocanville "A" unit of the Red Jacket Formation in the study area.

The olive-grey calcareous mudstones show platy partings and are commonly fossiliferous. Small (less than 1 cm across) thin-shelled pelecypods (*Modiolus* ?) are very common (Photo 2), and a few large (up to 4 cm across) unidentified pelecypod specimens were also found.

In the Wapella-Moosmin area, sandy, glauconitic, peloidal, oolitic and bioclastic limestone interbeds are numerous and widespread in the lower half of unit B. They thicken laterally into anomalous units displaying microstylolites, small-scale graded bedding, and some weakly defined, low- to high-angle (up to 25°) planar cross-bedding (Photo 3). The Tricent *et al.* Moosomin 4-28-14-31 well (Figure 16) contains these beds which are easily recognized in both core and on geophysical logs.

A reference core showing typical strata of the Gravelbourg Formation spanning the lower 3 m of the upper Gravelbourg, all of unit B and most of unit A of the lower Gravelbourg, is available from the Dahinda No.1 well (10-23-10-23W2).

Paleontology

Pelecypods and fish remains (i.e. bones, teeth and scales) dominate the megafaunal assemblage of the lower Gravelbourg. Unfortunately, none of these fossils are useful in chronostratigraphic assignments.

Pocock (1972) identified twenty-one terrestrial and seven marine palynomorph species from the lower Gravelbourg of southern Saskatchewan. He suggested an overall marine depositional environment for the lower Gravelbourg, as was the case for the Watrous Formation. He noted, however, that a precise paleo-ecological placement of this assemblage was impossible to make and suggested, therefore, a somewhat "restricted environment" of deposition as a compromise. He pointed to a greater number and diversity of terrestrial forms in the lower Gravelbourg than was recorded from the upper Watrous as evidence for less arid climatic conditions during lower Gravelbourg time.

Kybett and Nambudiri (1989 p.28) and Kreis (1989 p.133) reported a palynomorph assemblage quite similar to that obtained by Pocock from the lower Gravelbourg. However, palynomorphs were generally poorly preserved, particularly in unit B. This poor preservation is likely the result of slow deposition in an environment of high pH; such conditions are considered by Traverse (1988) to be corrosive to palynomorphs. Nevertheless, the presence of abundant microforaminifera in certain parts of unit B clearly indicates that at least some portions of it were deposited in a marine environment (Kybett and Nambudiri, 1989). The presence of the acritarch genus *Leiosphaeridia* in this unit further supports such a conclusion.

Ostracodes recovered in this study from core from the Wapella-Moosomin area suggest that the environment during unit B time was heavily influenced by freshwater to brackish-water conditions. A number of specimens of exclusive freshwater genera such as *Limnocythere* and *Darwinula* were found in parts of unit B. Specimens of the brackish-water ostracode genera *Norcanolella* were also recovered from scattered horizons. The presence of abundant "thin-shelled" pelecypods (*Modiolus* ?, Photo 2) in mudstones of this unit also suggests "stressed conditions". The weight of evidence suggests that unit B was deposited in waters of somewhat less than normal marine salinities.

In slight contrast, unit A of the lower Gravelbourg yielded a few species of *Leiosphaeridia* and a number of terrestrial palynomorphs, but no microforaminifera were found. The environmental placement of this palynological assemblage is difficult, but the absence of microforaminifera may indicate a more severely "restricted" depositional environment than was the case for unit B.

Member Boundaries

As noted earlier, a disconformity separates units A and B of the lower Gravelbourg in southeastern Saskatchewan. In the Wapella-Moosomin area, the disconformity truncates both unit A of the lower Gravelbourg and the upper Watrous in a northeasterly direction (Figures 4b, 11, 12 and 15, in pocket). Physical evidence of this disconformity can be seen in the Tricent *et al.* Moosomin 4-28-14-31 well (Figure 16 and borehole #9 on the cross-section in Figure 12, in pocket), where unit B of the lower Gravelbourg rests unconformably on truncated upper Watrous sediments. Core from this well shows a one metre-thick basal conglomerate above the disconformity composed of cherty, weathered upper Watrous clasts.

There has been inconsistency in the past in recognizing the upper contact of the lower Gravelbourg, partly because of the poorly defined division of the Gravelbourg sequence into its upper and lower members. It is proposed that the upper contact of the lower Gravelbourg be placed at the top of an interbedded argillaceous limestone and calcareous mudstone unit recognized as unit B in this paper. In core, this contact is sharp, showing a distinct contrast between the lithology of unit B and the overlying, generally non-calcareous and carbonaceous mudstones, siltstones and sandstones of the upper member of the Gravelbourg. However, on electrical logs the contact is sometimes less obvious, particularly in wells where sandstones of the upper Gravelbourg are cemented and resemble the argillaceous limestones of unit B of the lower Gravelbourg. Fortunately, the calcareous mudstones of unit B of the lower Gravelbourg are considerably less radioactive than the siltstones and mudstones of the overlying upper Gravelbourg, and a firm pick can thus be made on the gamma ray log (Figures 11 and 12, in pocket). The sharp contact and distinct lithological and palynological differences (see Table 1) between unit B of the lower Gravelbourg and the upper Gravelbourg suggest the presence of a diastem at this boundary, as will be discussed later in more detail.

Unit B of the lower Gravelbourg does not seem to be represented in the type section of the Gravelbourg Formation in the Tide Water Eastend Crown No.1 well (well #1 in Figure 4b, in pocket). Here, the upper member of the Gravelbourg appears to rest disconformably on unit A (as defined in this report) of the lower Gravelbourg. However, immediately east of this well, unit B overlies unit A throughout the region and up to the Wapella-Moosomin area where it oversteps unit A. Although unit B is not recognized in the type section, it is included in this report as the uppermost unit of what is summarily and informally referred to as the "lower Gravelbourg" of southern Saskatchewan. This decision was made because it is a distinctly marine unit showing greater lithological and paleontological similarity to unit A of the lower Gravelbourg than to the more marginal marine upper Gravelbourg.

The well-defined disconformity at the top of unit A is characterized by a zone of weathered dolomite, vug-filling secondary quartz (euhedral and bipyramidal), and bluish-grey chalcedonic chert, clearly separating units A and B in both southwestern and southeastern Saskatchewan (Kreis, 1988). Vigrass (1952) was the first to recognize a discontinuity at this contact, citing the presence of vuggy dolomitic limestone and chalcedonic chert, and a variation in the thickness of underlying strata, as evidence for an unconformity at this horizon. It is interesting to note that no such lithological evidence suggestive of an unconformity was detected in the cuttings from the top of unit A in the wells numbered 3 to 9 of the cross-section in Figure 4b (in pocket) - the centre of the basin. The absence of evidence for a disconformity between units A and B in the intervening wells may indicate that unit A was only exposed briefly or, perhaps, not exposed at all in the more central portions of the basin.

Distribution

Lower Gravelbourg sediments extend from their type area in southwestern Saskatchewan to their zero limit in the Wapella-Moosomin region of southeastern Saskatchewan (see Figures 4a and 4b). Within the Wapella-Moosomin area unit B oversteps unit A in a northeasterly direction. Both units A and B form wedge-shaped bodies which thicken in a southwesterly direction (Figures 18 and 19, in pocket). Given the evidence for an unconformity between units A and B at the basin margin in the southeast, it is probable that some removal of unit A has taken place in this region. Cross-sections (Figures 4b, 11 and 12, in pocket) show the truncation of unit A in a north and easterly direction. The parallelism and near coincidence of the zero limits of unit A and unit B in the study area (Figure 18, in pocket), as well as a general attenuation of these sediments in that direction, suggests that these limits are likely close to the depositional limits of these units.

Age and Correlation

The Gravelbourg Formation is commonly assigned a Bajocian age (Paterson, 1968; Brooke and Braun, 1972). The lower Gravelbourg is correlated with the Kline Member of the Nesson Formation in northeastern Montana and northwestern North Dakota (Imlay, 1980) (Figure 14), but correlation with strata in Manitoba is unclear. Present usage as illustrated in the Petroleum Catalogue (1984, p.7) of the Manitoba Department of Energy and Mines appears to include all Middle Jurassic strata overlying the Amaranth in the Reston Formation. By implication, this would make the Reston Formation equivalent to both the Shaunavon and Gravelbourg formations of Saskatchewan. On the basis of lithological characteristics, however, the Reston appears to be equivalent to the lower Gravelbourg sequence, making the Shaunavon and upper member of the Gravelbourg by implication equivalent to the Melita Formation. Unfortunately, Stott (1955) did not designate type sections for the Reston and Melita sequences when he introduced them, and the picture is further confused by two slightly differing stratigraphic schemes in two charts present in the same publication (see Figure 14).

Gravelbourg Formation - Upper Member

Lithology

The upper Gravelbourg member is generally characterized by greenish-grey to olive-grey, fossiliferous, and variably calcareous shale in southwestern Saskatchewan. In southeastern Saskatchewan the upper Gravelbourg is most commonly characterized by interbedded and interlaminated sandstone, siltstone and mudstone. The sandstones tend to be very light grey and are composed of very fine- to fine-grained clear quartz. The siltstones and mudstones are medium grey to olive-grey, typically sandy, non-calcareous and carbonaceous and contain trace amounts of pyrite and siderite.

Paleontology

Poorly preserved pelecypods (unidentified) and fish remains comprise the megafauna found in the upper Gravelbourg. A meagre microfaunal assemblage comprising a few species of Foraminifera and ostracodes has been reported from the upper Gravelbourg by Wall (1960). He suggested that the microfauna point to conditions other than normal marine, that is, an environment of reduced salinities.

The palynological study by Pocock (1972) also pointed to an environment of reduced salinities. He envisaged most of the upper Gravelbourg to have been deposited in extensive swamps bordering an inland sea that occupied the extreme southernmost part of Saskatchewan. Kreis (1989) and Kybett and Nambudiri (1989) reported the presence of many of the same terrestrial

Table 1 - Typical Palynomorph Assemblages. After Kreis (1989).

	Stratigraphic Units									
	LGA	LGB	UG	LS1	US	RM	MMA	MMB	BMA	BMB
Terrestrial Species										
Baculatisporites truncatus	-	-	-	X	-	-	-	-	-	-
Bennettiteaepollenites canadensis	-	-	X	-	-	-	X	-	-	-
Bennettiteaepollenites lucifer	-	-	-	-	X	-	X	-	-	-
Bennettiteaepollenites shaunavonensis	-	-	-	X	-	-	-	X	-	-
Calamospora mesozoica	-	-	X	X	-	X	-	-	X	-
Callialasporites trilobatus	X	-	-	X	-	-	-	-	-	-
Ceratosporites spinosus	-	-	-	-	X	-	-	-	-	-
Cerebropollenites macroverrucocus	-	-	X	-	-	-	-	X	-	-
Cerebropollenites mesozoicus	-	-	-	-	-	X	-	-	-	-
Cerebropollenites sp.	-	-	-	-	X	-	-	-	-	-
Classopollis classoides	X	-	-	-	-	-	-	X	-	-
Classopollis itunensis	-	-	X	-	-	X	X	-	-	-
Concavissimisporites delcourtii	-	-	-	-	-	-	X	-	-	-
Concavissimisporites southeyensis	-	-	X	X	-	X	-	-	-	-
Concavissimisporites subgranulatus	-	-	-	-	-	-	-	-	X	-
Concavissimisporites sp.	X	-	-	-	-	-	-	-	-	-
Corrugatisporites amplectiformis	-	-	-	-	-	X	-	-	-	-
Corrugatisporites wallii	-	-	-	-	-	X	X	-	-	-
Cyathidites minor	-	-	X	-	-	X	-	-	-	-
Cycadopites jansonii	-	-	-	-	X	-	-	-	-	-
Cycadopites minimus	-	-	-	-	X	-	-	X	X	-
Deltoidospora harrisii	-	-	X	-	X	-	-	X	-	-
Deltoidospora minor	-	-	-	-	X	-	-	X	X	-
Dictyophyllidites sp.	-	-	-	-	-	-	X	-	-	-
Dictyotriletes crateris	-	-	X	X	-	-	-	-	-	-
Distanulisporites verrucosus	-	-	-	X	-	-	-	-	-	-
Ericommiidites troedsonii	-	-	-	-	-	X	-	-	-	-
Exesipollenites tumulus	-	-	-	-	-	-	-	-	X	-
Gleicheniidites delicatus	-	-	-	-	-	-	-	X	-	-
Gleicheniidites granulatus	-	-	-	-	X	-	-	-	-	-
Gleicheniidites minor	-	-	-	-	X	-	-	-	-	-
Gleicheniidites nilssonii	-	-	X	-	-	-	-	-	-	-
Gleicheniidites rouseii	-	-	-	-	X	-	-	-	-	-
Harrisispora equiexinus	-	-	-	-	-	-	-	-	X	-
Inaperturopollenites turbatus	-	-	X	-	X	-	X	-	-	-
Lycopodiumsporites bacculatus	-	-	-	-	X	-	-	-	-	-
Lycopodiumsporites dejerseyi	X	-	-	-	-	-	-	-	-	-
Lycopodiumsporites pseudoannotinus	-	X	-	-	-	-	-	-	-	-
Manumia verrucata	-	-	-	-	-	-	-	-	X	-
Murospora bicollateralis	-	-	X	-	X	-	-	-	-	-
Murospora minor	X	-	-	-	-	-	-	-	-	-
Murospora sp.	X	-	-	-	-	-	-	-	-	-
Ovalipollis canadensis	-	-	X	-	-	-	-	-	-	-
Pityosporites divulgatus	-	X	X	-	-	-	-	-	-	-
Platysaccus lopsinensis	-	-	-	-	-	-	X	-	-	-
Podocarpidites langii	-	-	-	-	-	-	X	-	-	-
Podocarpidites wapellaensis	-	-	X	-	-	X	-	-	-	-
Protoconiferus microsaccus	-	-	-	X	-	-	-	-	-	-
Protopicea exilioides	-	X	X	-	-	X	-	-	-	-
Reticulatisporites jurassicus	-	-	-	X	-	-	-	-	-	-

	Stratigraphic Units									
	LGA	LGB	UG	LS1	US	RM	MMA	MMB	BMA	BMB
Reticulatisporites sp.	.	.	.	.	.	X	.	.	.	.
Triangulopsis discoidalis	.	.	X	.	.	X	.	.	.	.
Marine Species										
organic-walled foraminifera	.	X	.	.	.	.	X	.	.	.
dinoflagellates (indeterminate)	.	.	.	X	.	.	.	.	.	.
Chytroeisphaeridia variabilis	.	.	.	.	X	.	.	.	.	.
Comasphaeridium sp.A	.	.	.	.	.	.	X	.	.	.
Cymatiosphaera sp.	.	.	.	.	.	.	.	.	X	.
Gonyaulacysta jurassica	.	.	.	.	.	.	.	.	X	.
Gonyaulacysta ornata	.	.	.	.	.	.	.	.	X	.
Gonyaulax canadensis	.	.	.	.	X	.	.	.	.	.
Leiofusa deunffii	.	.	.	.	X	.	.	.	X	.
Leiosphaeridia hyalina	.	.	.	.	.	.	X	.	.	.
Leiosphaeridia staplinii	X	.	.	X	.	.	.	X	X	.
Leiosphaeridia tangentensis	X	X	.	X	.	.	.	X	.	.
Leiosphaeridia sp.	.	X	.	.	.	.	.	.	.	.
Rugidinium ornatum	.	.	.	.	.	.	.	X	.	.
Rugidinium undulatum	.	.	X	.	.	.	.	.	.	.
Rugidinium sp.	.	.	.	.	.	.	.	X	.	.
Solisphaeridium deflandrei	.	.	.	.	.	.	.	X	.	.
Tasmanites clairmontensis	.	.	.	.	X	.	.	.	.	.
Tasmanites suevicus	.	.	.	X	.	X	.	.	.	.
Tasmanites yarboensis	.	.	X	.	.	.	.	.	.	.

Abbreviations:
LGA - Lower Gravelbourg, Unit A
LGB - Lower Gravelbourg, Unit B
UG - Upper Gravelbourg
LS1 - Lower Shaunavon, Unit 1
US - Upper Shaunavon
RM - Rocanville Member
MMA - Moosomin Member, Moosomin "A"
MMB - Moosomin Member, Moosomin "B"
BMA - Burrows Member, Burrows "A"
BMB - Burrows Member, Burrows "B"

palynomorphs described by Pocock, but also noted the presence of marine palynomorphs *Leiosphaeridia staplinii*, *Rugidinium undulatum*, and *Tasmanites yarboensis* in a number of samples across southern Saskatchewan (Table 1).

The presence of a diverse and relatively abundant terrestrial flora, rare ostracode and foraminiferal species indicative of brackish or the most marginal of marine environments, and some "marine" palynomorphs suggests deposition in a near-shore, coastal depositional environment bordered by extensive swamps.

Member Boundaries

As previously discussed, the contact between the upper and lower Gravelbourg is sharp when seen in core, but is less obvious on a geophysical log. The upper boundary is described by Christopher (1964) as conformable for southwestern Saskatchewan. In southeastern Saskatchewan, however, lithological similarity between the upper Gravelbourg, Lower Shaunavon, and Upper Shaunavon members, makes separation of these units on the basis of lithology and geophysical log signature very difficult (Nordquist, 1955; Francis, 1956; Klingspor, 1958; Wall, 1960; Kreis, 1988 and 1989), and therefore the nature of the upper boundary is uncertain. Lithofacies changes in both the upper Gravelbourg and the Lower Shaunavon, but particularly within the Lower Shaunavon Member, are the cause of this difficulty. In southwestern Saskatchewan, the Lower Shaunavon is a lithographic limestone unit of uniform thickness (approximately 30 to 35 m) and character. However, it becomes increasingly siliciclastic-rich and interbedded towards southeast Saskatchewan to a point where it is unrecognizable on geophysical logs from this region. This problem prompted Kreis (1988) to invoke a somewhat arbitrary cut-off separating the upper member of the Gravelbourg Formation and the Shaunavon Formation from the proposed Red Jacket Formation of southeastern Saskatchewan (see Figures 4a, 4b, and 11, in pocket). This cut-off line demarcates the approximate point to which the lithographic limestone beds of the Lower Shaunavon can be readily recognized, and therefore, the limit to which the established stratigraphy can be used.

Distribution

The upper Gravelbourg extends westward from the arbitrary lithofacies cut-off to the type area in southwestern Saskatchewan. To the east, the unit is included in the lowermost part of the Red Jacket Formation (Figures 4a and 4b, in pocket).

Age and Correlation

The upper member of the Gravelbourg is generally assigned a Bajocian age in the literature, as is the whole Gravelbourg Formation. It is correlated with the Tampico Shale Member of the Piper Formation of northeastern Montana and northwestern North Dakota. It is also considered to be correlative with the lowermost portion of the Rocanville Member of the Red Jacket Formation to be proposed later (Figure 14).

The Shaunavon Formation

The Shaunavon Formation was defined in southwestern Saskatchewan and was formally divided into an Upper and Lower Member by Milner and Thomas (1954). The terms Lower and Upper Shaunavon are used throughout this report. In addition, the Lower Shaunavon is subdivided into units 1 and 2 in this study.

Shaunavon Formation - Lower Member

Lithology

Unit 1 at the base of the Lower Shaunavon Member is composed of stacked beds of very fine- to fine-grained quartzose sandstone interbedded with mudstone. Near the base of this unit, the mudstones are commonly variegated. Thin beds of limestone are common near the top of the unit.

In contrast, Unit 2 is composed of the remarkably uniform, widespread, tan to cream, fossiliferous, brittle and earthy lithographic limestone described by (Christopher, 1964) as typical for the Lower Shaunavon in southwestern Saskatchewan. It is also commonly sandy and oolitic within the upper 6.0 m (20 ft) in this region; however, it becomes increasingly sandy (quartz-rich) and interbedded with very fine- to fine-grained, clear quartz sandstone and greenish-grey to olive-grey mudstone towards southeastern Saskatchewan.

Paleontology

Although locally abundant, megafossils in the Lower Shaunavon are of limited diversity. Pelecypods, corals, high-spired gastropods, brachiopods, echinoids and algae comprise the megafossil assemblage (Christopher, 1964; see also Paterson, 1968). Wall (1960) and Brooke and Braun (1972) recorded a scarce, but dominantly marine, microfaunal assemblage of Foraminifera and ostracodes from this unit.

Pocock (1972) identified twenty-six non-marine, and twenty-four marine palynomorph species. An abundance of dinoflagellates in this unit led Pocock to surmise a marine depositional environment for the Lower Shaunavon. The occurrence of *Botryococcus* in moderate abundance in the Lower Shaunavon was furthermore interpreted as being suggestive of a shoreline backed by extensive freshwater marshes, at least in some areas.

All samples taken from the Lower Shaunavon for palynological investigation in the present study were taken from unit 1 in south central Saskatchewan (e.g. Lsd. 1-17-20-23W2 at 744.6 m) (Table 1). Several of the palynomorph species recovered were already reported by Pocock (1972), but the abundance of dinoflagellates observed by Pocock is not apparent in the present study. The relative scarcity of dinoflagellates in unit 1 in south central Saskatchewan may suggest that the Lower Shaunavon coastline was quite close to the study area at this time. The apparent scarcity and variation in numbers of dinoflagellates may also be partially attributed to slow deposition in a high pH environment (Traverse, 1988) which did not affect all regions equally.

Member Boundaries

Christopher (1964) interpreted the contact between the upper Gravelbourg and the Lower Shaunavon to be conformable and gradational in southwestern Saskatchewan. However, the contact between the Upper and Lower Shaunavon members is distinctly disconformable in this region, sharply delineated by an irregular erosional surface (Christopher, 1964). Conglomerates comprising eroded lithographic limestone and abraded coral fragments derived from the underlying Lower Shaunavon sequence are found locally at this contact in southwestern Saskatchewan (Paterson, 1968).

Unit 1 appears to be a transitional unit between the upper member of the Gravelbourg and the Lower Shaunavon Member in southeastern Saskatchewan. This transitional zone has also been recognized by Christopher (1989, pers. comm.). It first appears in well number 6 (i.e. 14-29-7-29W2) of the regional cross-section in Figure 4b (in pocket). From this location, unit 1 extends eastward to the arbitrary lithofacies cut-off outlined earlier (see Figures 4a and 4b, in pocket). Beyond this boundary it is very difficult to distinguish on geophysical logs from the underlying upper Gravelbourg and the overlying unit 2 of the Lower Shaunavon, which also changes lithofacies becoming increasingly siliciclastic-rich and interbedded towards southeast Saskatchewan (Figure 4b in pocket).

Distribution

The Lower Shaunavon sequence extends from the arbitrary lithofacies cut-off to the type area in southwestern Saskatchewan (Figures 4a and 4b, in pocket).

Age and Correlation

The presence of a variety of corals, such as the genus *Actinastrea* and the pelecypod *Gervillia Montanaensis* indicate an exclusive Bajocian age for this unit (Imlay, 1967, ps. 35 and 78).

The Lower Shaunavon is correlated with the Firemoon Limestone Member of the Piper Formation of northeastern Montana and northwestern North Dakota (Imlay, 1980). It is considered equivalent to the upper portion of the Rocanville Member of the Red Jacket Formation to be proposed for southeastern Saskatchewan (Figure 14).

A core covering almost the entire Lower Shaunavon Formation is found in the TW Imp Avonhurst Cr 1-29-19-16 well (Lsd. 1-29-19-16W2). The oxidized mudstone observed at approximately 838.2 m (2750 ft) in this well suggests a brief period of exposure early during Lower Shaunavon deposition. On the basis of its stratigraphic position, it is possible that this horizon is coeval with the brief hiatus postulated and described by Christopher (1964, p. 19) within the lower 3 m (10 ft) of the Lower Shaunavon in southwestern Saskatchewan.

Shaunavon Formation - Upper Member

Lithology

Generally, the Upper Member of the Shaunavon Formation is characterized by very fine- to fine-grained quartz sandstone, calcareous shales, dolomites, fossil coquinas, and sandy to argillaceous limestones which are locally oolitic (Christopher, 1964). The shales range from olive-grey to greenish-grey and are locally variegated. A conglomerate composed of eroded lithographic limestone with abraded coral fragments is commonly found at the base of the Upper Shaunavon.

Paleontology

Pelecypods are by far the most abundant and diverse megafossils present in the Upper Shaunavon, but specimens of echinoderms, gastropods, plants, annelids (i.e. calcified burrows), brachiopods and even rare corals were also recovered by Paterson (1968). The coral *Actinastrea* cf. *A. hyatti*, found in the basal conglomerate of this unit in southwestern Saskatchewan, has most likely been reworked from the underlying Lower Shaunavon (Paterson, 1968).

A diverse assemblage of microfossils characterizes the Upper Shaunavon, and includes a variety of ostracodes and Foraminifera that represent a wide range of environments (Wall, 1960; Brooke and Braun, 1972). Ostracode genera, indicative of freshwater conditions, such as *Darwinula*, *Limnocythere* and *Metacypris* are most common near the top of this unit in association with charophytes. On the other hand, the presence of ostracodes such as *Norcanolella* and *Aparchitocythere*, and the agglutinated foraminifera *Involutina* (formerly *Ammodiscus*) indicate brackish to near-normal marine waters.

Member Boundaries

As previously noted, the contact between the upper and lower members of the Shaunavon Formation is disconformable in southwestern Saskatchewan, as is the contact between the Upper Shaunavon and the overlying strata of the Vanguard Group. Christopher (1964) described this upper contact as being sharp, generally irregular, and at the base of a thin basal sandstone unit commonly characterized by scattered conglomerates composed of abundant and well-worn *Gryphaea* and other pelecypods.

Distribution

The Upper Shaunavon sequence of southeastern Saskatchewan can be readily correlated from the arbitrary cut-off to the type section in southwestern Saskatchewan. East of this boundary, the Upper Shaunavon becomes part of the newly proposed Red Jacket Formation.

Age and Correlation

Although no age-diagnostic fossils have been found to date in the Upper Shaunavon, it is commonly assigned a Bathonian age in the literature. This is done mainly on the basis of its stratigraphic position between the underlying Lower Shaunavon with its Late Bajocian fossil indicators and the overlying Rierdon Shale (i.e. sub-group of the Vanguard Group) which can be readily assigned a Bathonian-Callovian age on ammonite evidence.

The Upper Shaunavon is correlated with the Bowes Member of northeastern Montana and northwestern North Dakota (Imlay, 1980). It is also considered to be equivalent to the Moosomin and Burrows members of the proposed Red Jacket Formation of southeastern Saskatchewan (see Figure 14).

The Rierdon Formation

The Vanguard Formation was originally introduced by Milner and Thomas (1954) and divided into Upper, Middle and a Lower members. Christopher (1974) subsequently renamed these members and raised them to formation status. In ascending order they are (oldest to youngest): Rush Lake, Roseray and Masefield formations. He also raised the Vanguard to group status and introduced the term Rierdon Shale sub-group (i.e. Rierdon Formation) for the combined Rush Lake and Roseray strata stating that "In the sense that the Rush Lake and Roseray formations are subdivisions of the Rierdon, the latter is a sub-group..." (Christopher, 1974, p8). In effect, the Rush Lake Shale is restricted to the area of Roseray sandstone distribution, as is illustrated between wells 2 and 7 on the regional cross-section in Figure 4b (in pocket). Beyond the area of Roseray sandstone distribution the Roseray and Rush Lake Shale combine to become the Rierdon Shale.

The Masefield Shale and much of the Rierdon Shale is absent in the study area (Figure 4b, in pocket) having been removed by erosion sometime during Late-Jurassic to Early-Cretaceous time.

Lithology

The Rierdon Shale is everywhere characterized by dark greenish-grey, calcareous shale, calcareous mudstone and greenish-grey marlstone. There is a transition into sandy mudstone and sandstone in the direction of the area of Roseray sandstone distribution (Figure 4b, in pocket).

Paleontology

Megafossils from the Rierdon Shale in the Wapella-Moosomin area consist largely of fragments of belemnite guards, pelecypods (e.g. *Gryphaea nebrascensis*) and ammonites belonging to the genus *Kepplerites*. Echinoids and gastropods are also found but are less common.

Samples taken in the course of the present study from the Rierdon Shale in the Central Del Rio Red Jacket No. 6-19 (Lsd. 6-19-13-32W1) well yielded a foraminiferal and ostracode microfaunal assemblage that is very similar to the microfaunal assemblage IV and V reported by Brooke and Braun (1972) from wells proximal to this location. Brooke and Braun (1972) envisaged a normal or near-normal marine depositional environment for the Rierdon Shale in this area.

A variety of microfossils from the Rierdon Shale have been described in the literature. For a detailed discussion of Foraminifera and ostracode fauna present in the Rierdon Shale (i.e. Lower Vanguard and Middle Vanguard) see: Wall (1960), Guliov (1967), and Brooke and Braun (1972).

Pocock (1972) described the change in palynological assemblages between the Upper Shaunavon and Lower Vanguard (i.e. Rierdon Shale equivalent) as abrupt and distinctive. He reported a very large, dominantly marine palynological assemblage for the Lower Vanguard (Rierdon Shale) of southern Saskatchewan but relatively few species were considered useful for long distance correlation or age dating. On the basis of the palynomorphs present he assigned an upper Middle or lower Upper Jurassic age.

Boundaries

The Rierdon Shale is bound by the overlying Masefield Shale Formation and the underlying Upper Member of the Shaunavon Formation. Both contacts are considered to be disconformable in southwestern Saskatchewan (Christopher, 1974). The base of the Rierdon Shale in the study area will be discussed in detail in a later section.

Distribution

The Rierdon Shale is distributed throughout most of southern Saskatchewan; however, much of the uppermost portion in southeastern Saskatchewan was removed below the sub-Cretaceous unconformity. Its distribution and erosional edge in the Wapella-Moosomin area is shown on an isopach map (Figure 8, in pocket).

Age and Correlation

Recent studies by Imlay (1980) and Poulton (1984) suggest that the ammonites of the Rierdon Shale indicate a Late Bathonian to Early Callovian age. The Rierdon Shale of Saskatchewan is correlated without any problem both lithologically and faunally with the Rierdon Formation of northeastern Montana and northwestern North Dakota (Imlay, 1980). The correlation with strata in Manitoba, however, is unclear but the Rierdon Shale appears to be approximately equivalent to the Melita Formation (Figure 14).

The Red Jacket Formation

The Red Jacket Formation was defined by Kreis (1988) to include Middle Jurassic strata of southeastern Saskatchewan that are equivalent to the Shaunavon and upper member of the Gravelbourg Formation of southwestern and south-central Saskatchewan (Figure 5). Kreis proposed this solution because of lithofacies changes in these units, particularly in the Lower Shaunavon, which make correlation difficult between southwestern and southeastern Saskatchewan. An arbitrary cut-off in southeastern Saskatchewan was chosen to separate the Red Jacket Formation from these other units (Figures 4a, 4b and 11, in pocket).

The Red Jacket Formation takes its name after a village in Township 14, Range 32 west of the First Meridian. The type section chosen by Kreis (1988) is fully cored in the Tide Water North Wapella Crown 14-22-15-1 well (Lsd. 14-22-15-1 west of the Second Meridian) between 665.4 to 734.6 m depth (2183-2410 ft) (see Figure 20, and Appendix C.2 for core description).

In general, recovery of the 3.8 cm (1.5 in) diameter wireline core in this well was fair (approx. 60 to 80 percent) to good (approx. 80 to 100 percent); however, recoveries were considerably poorer over a few short intervals of approximately 3.0 m (10 ft) thickness. The core is largely broken up owing to considerable use, and many contacts are not well preserved making them difficult to place. This is especially true in highly interbedded and interlaminated sandstone/mudstone sections of the core.

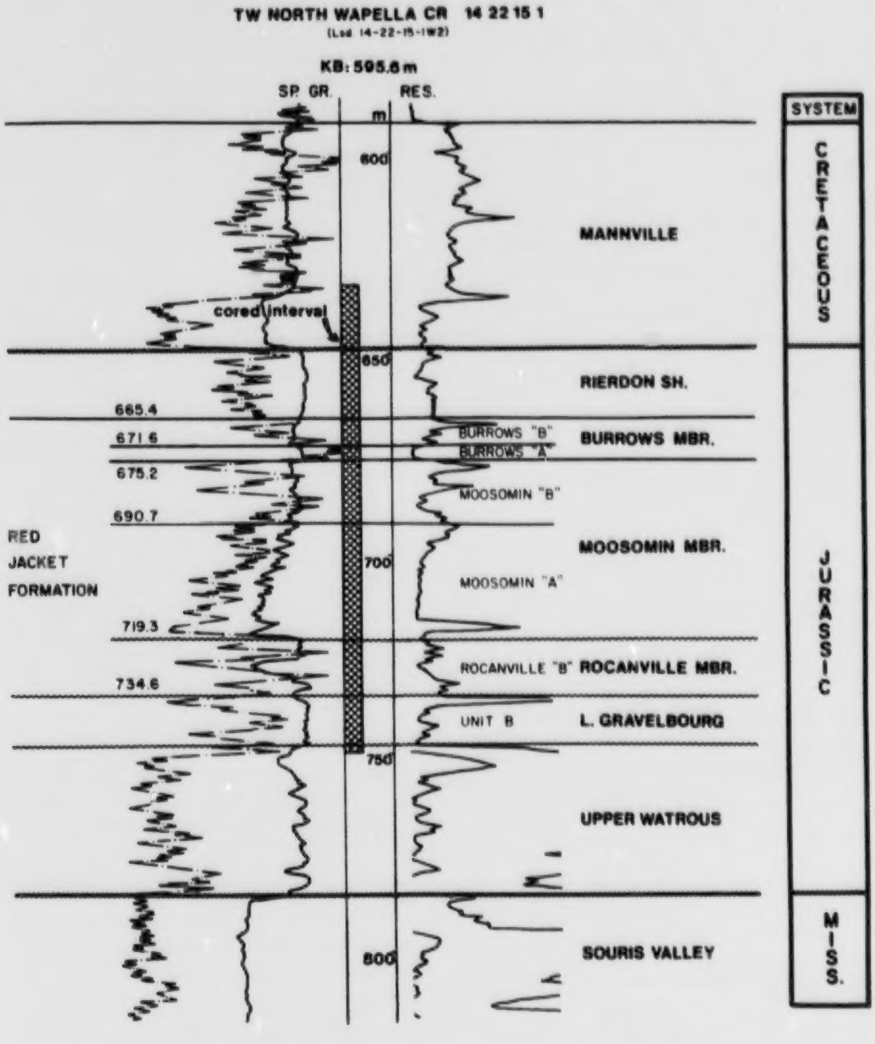

TW NORTH WAPELLA CR 14 22 15 1
(Lsd 14-22-15-1W2)
KB: 595.6 m
SP. GR.
RES.
m
600
650
700
750
800
cored interval
665.4
671.6
675.2
690.7
719.3
734.6
RED JACKET FORMATION
MANNVILLE
RIERDON SH.
BURROWS "B"
BURROWS "A"
BURROWS MBR.
MOOSOMIN "B"
MOOSOMIN MBR.
MOOSOMIN "A"
ROCANVILLE "B"
ROCANVILLE MBR.
UNIT B
L. GRAVELBOURG
UPPER WATROUS
SOURIS VALLEY
SYSTEM
CRETACEOUS
JURASSIC
MISS.

Figure 20 - TW North Wapella Cr 14-22-15-1 well showing cored interval through type section of the Red Jacket Formation and its members. Note: Units Rocanville "A" and Rocanville "C" of the Rocanville Member are not present.

The Red Jacket Formation is formally divided into three members (Kreis, 1988) all of which are named after a village near the type section (Figure 20). They are, from oldest to youngest the Rocanville, Moosomin and Burrows members. The divisions are dependent on recognition of a number of lithological changes and discontinuities which are used as unit boundaries. Each member is further divided into the following units: Rocanville "A", "B", and "C"; Moosomin "A" and "B"; and Burrows "A" and "B". In addition, Moosomin "A" is subdivided in places into two subunits, Moosomin "A1" and Moosomin "A2", to facilitate a detailed description. Not all of these units are present in the type borehole (Figure 20).

The type section for the Rocanville Member was selected between 719.3 to 734.6 m depth (2360-2410 ft) in the same type section as for the Red Jacket Formation (Kreis, 1988). However, subsequent work has shown that some of the uppermost and lowermost Rocanville strata are missing in the TW North Wapella Cr 14-22-15-1 well. Approximately 15 m (50 ft) of additional Rocanville strata were subsequently found in a number of wells in the study area. Therefore, a second reference borehole, with a more completely preserved section is proposed for the Rocanville Member in the Tide Water Wapella No. 6-33 well (Lsd. 6-33-14-1 W2) between 731.5 to 760.5 m depth (2400-2495 ft) (see Figure 21, and Appendix C.3 for core descriptions).

The Moosomin Member is represented in the type section for the Red Jacket Formation between 675.2 to 719.3 m depth (2215-2360 ft), while the Burrows Member occupies the interval between 665.4 to 675.2 m depth (2183-2215 ft) in the same borehole.

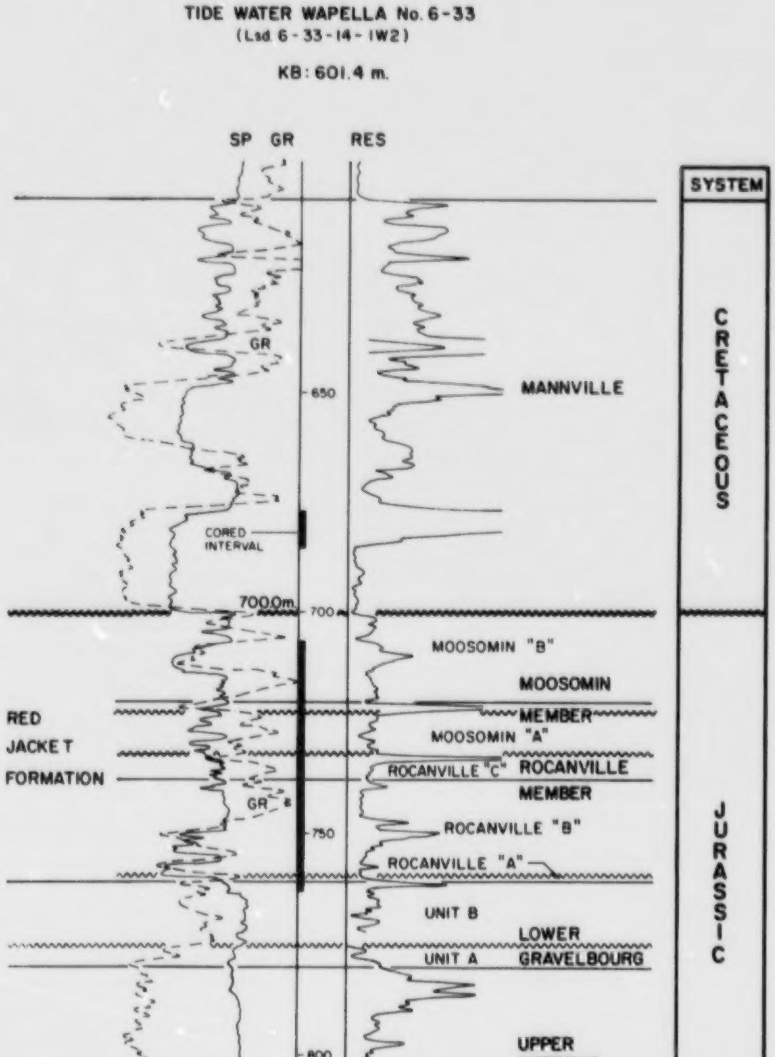

TIDE WATER WAPELLA No. 6-33
(Lsd. 6-33-14-1W2)
KB: 601.4 m.
SP
GR
RES
GR
650
MANNVILLE
CORED INTERVAL
700.0m
700
MOOSOMIN "B"
MOOSOMIN
MEMBER
RED
JACKET
FORMATION
MOOSOMIN "A"
ROCANVILLE "C"
ROCANVILLE
MEMBER
GR
750
ROCANVILLE "B"
ROCANVILLE "A"
UNIT B
LOWER
UNIT A
GRAVELBOURG
800
UPPER
WATROUS
LOWER
WATROUS
819.9m.
MISSISSIPPIAN
SYSTEM
CRETACEOUS
JURASSIC
TRIAS.
MISS.

Figure 21 - Tide Water Wapella No 6-33 well showing cored interval through reference section for the Rocanville Member.

From a historical point of view it is interesting to note that Nordquist (1955) had already proposed a similar scheme for the east flank of the Williston Basin, suggesting also that it could be applied in southeastern Saskatchewan. He proposed a different usage of the Piper Formation as was originally defined by Imlay (1948), in effect dividing Imlay's Piper Formation into an upper unit, the Piper Formation, and a lower unit, the Nesson Formation. He further divided his newly defined Piper Formation into three members, in ascending order the Tampico Shale, Firemoon and Bowes. Likewise, the Nesson Formation was divided into three members in ascending order the Poe Evaporite, Picard Shale, and Kline Member. With regards to equivalencies, Nordquist (1955, p. 100) suggested that his Piper Formation "...is the apparent stratigraphic equivalent of the Shaunavon formation and the upper unnamed member of the Gravelbourg formation of Milner and Thomas (1954) in Saskatchewan". He also recognized that in the central part of North Dakota the two members of the Shaunavon Formation become lithologically similar and are difficult to separate from each other and from the underlying upper member of the Gravelbourg Formation suggesting that "on the east flank of the Williston basin the term Piper formation can be used to great advantage". Thus, it would appear that the proposed Red Jacket Formation and the Piper Formation *senso stricto* as defined by Nordquist (1955) are one in the same.

The term Piper Formation was not adopted in this report in order to avoid confusion with the use of the term "Piper Formation" in a wider context in the conterminous area of North Dakota. It is evident from a stratigraphic column published by the North Dakota Geological Survey (1986) that the name "Piper Formation" still reflects the original definition of Imlay (1948), including therefore all Middle Jurassic strata underlying the Rierdon Formation - a marked contrast to Nordquist's (1955) recommended use and restrictions.

The scheme introduced in Manitoba by Stott (1955) for strata which appear to be the stratigraphic equivalent of the Red Jacket Formation includes (from oldest to youngest) the Reston and possibly part of the Melita Formation. Kreis (1988) did not adopt this nomenclature for two reasons: firstly, no type section was established for either the Reston or Melita Formation, and secondly, Kreis (1988, p. 217) suggested that "It would appear that inconsistencies in the definition and correlation of the Reston and Melita Formations in Manitoba require resolution before their correlation with Saskatchewan strata can be understood". The correlation chart in Figure 14 reflects some of these inconsistencies. It shows the two different correlations implied by Stott between the Reston Formation of Manitoba and the Shaunavon and Gravelbourg Formations of Saskatchewan. The writer agrees with Francis (1956) that, on cross-sections by Stott (1955), the Reston Formation is placed much higher in east-central Saskatchewan than in southeastern Saskatchewan.

The Red Jacket Rock Sequence

Kreis (1988, p.214) summarized the lithology of the Red Jacket Formation as "...a complex succession of sandstones, siltstones, mudstones and minor carbonates". Generally, very fine- to fine-grained, clear quartz sandstones dominate the section.

The mudstones range from olive-grey to greenish-grey and are variegated in some units. The greenish-grey and variegated varieties are commonly calcareous and/or dolomitic. The minor carbonates are typically thin (less than 3 m) argillaceous limestones which in some units are dolomitic (e.g. Rocanville "B"). A thin interbed (less than 2 m) of sandy and fossiliferous lithographic limestone occurs in Rocanville "C" at the top of the Rocanville Member in the Wapella Field.

Formational Boundaries

In the type section, the base of the Red Jacket Formation is at a depth of 734.6 m (2410 ft) below K.B.. The pick is based on a well-log signature, since the contact is not present in the core. Cores from other wells, however, show it to be a sharply delineated and clearly recognizable contact. For example, in the reference section for the Rocanville Member (i.e. Tide Water Wapella No 6-33), a thin (approximately 90 cm thick) sandy, carbonaceous siltstone unit representing a remnant of Rocanville "A" at the base of that member is in sharp contact with an argillaceous limestone bed at the top of the underlying unit B of the lower Gravelbourg. Also, the palynological assemblage in Rocanville "A" is dominantly terrestrial while unit B of the lower Gravelbourg is marine, a contrast which implies a significant shift in depositional environments between these units and suggests a discontinuity at the base of the Red Jacket Formation.

Generally, the base of the Red Jacket Formation can be readily picked on geophysical logs in the Wapella-Moosomin area where, for the most part, porous sandstones of Rocanville "B" rest disconformably on argillaceous limestones of the underlying unit B of the lower Gravelbourg. However, to the south and west of the study area, the base of the Red Jacket Formation may be difficult to recognize on geophysical logs in a number of wells. The difficulty in these regions is caused by the similarity in resistivity and porosity log response between the sandstones and siltstones at the base of a thickened Rocanville "A", and that of the mudstones, siltstones, minor sandstones, and interbeds of argillaceous limestone in the underlying unit B of the lower Gravelbourg in this area. Fortunately, the mudstones and argillaceous limestones of unit B of the lower Gravelbourg tend to show a lower gamma ray response than the overlying siltstones of Rocanville "A", and the contact therefore can be discriminated on that basis (Figure 11, in pocket).

The upper boundary of the Red Jacket Formation is placed at the base of the calcareous mudstones of the overlying Rierdon Formation. In the study area, calcareous mudstones of the Rierdon Formation commonly overlie a fossiliferous, calcite-cemented sandstone subunit at the top of the Red Jacket Formation (i.e. top of Burrows "B" of Burrows Member). This sandstone subunit is typically less than 1.5 m thick, very fine to fine grained, calcite-cemented, light olive-grey, silty and argillaceous, and contains minor amounts of pyrite and trace amounts of glauconite. It is the abundance of well-worn *Gryphaea nebrascensis* and other pelecypods, however, which characterize this subunit (Photo 4). In the type section, the upper boundary of the Red Jacket Formation is placed at a depth of 665.4 m.

Kreis (1988) interpreted this calcite-cemented and *Gryphaea*-bearing sandstone subunit as a lag deposit at the base of the overlying calcareous mudstones of the Rierdon Formation and suggested the base of this subunit was disconformable. This placement would be in line with Christopher's (1964) contention that *G. nebrascensis* is a typical fossil of the Rierdon Formation. Moreover, in cores from the study area, the base of this subunit is found to be sharply delineated with erosional features and it would therefore appear to be a logical place for selecting the base of the Rierdon and thus, by implication, the top of the Red Jacket Formation. However, Kreis (1988, p. 214) had second thoughts and argued that "...The presence of *G. nebrascensis* in this sandstone was not detected...where this sandstone is not highly calcite-cemented". Hence, he suggested that only where this thin sandstone subunit is well calcite-cemented due to the presence of abundant *Gryphaea* is it distinguishable on geophysical logs from the underlying sandstones of the Red Jacket Formation. Therefore, and thus for purely practical log picking purposes, he proposed that this subunit be included in the uppermost sequence of the Red Jacket Formation (i.e. top of Burrows "B" of Burrows Member) - a practice adopted also herein.

The contact at the base of the *Gryphaea*-bearing sandstone in the study area is quite similar to the boundary described by Christopher (1964, p. 11) between the Lower Vanguard (i.e. Rierdon Shale equivalent) and the Upper Shaunavon in southwestern Saskatchewan. He characterized the contact there to be "...everywhere sharp, generally irregular, and underlies a thin basal sandstone unit with scattered conglomerates and abundant worn *Gryphaea* and other pelecypods shells". This thin, basal sandstone in the southwest is thus remarkably similar in terms of position, lithology and possible origin to the sandstone subunit included in the top of the Red Jacket Formation and described in detail in this study.

Generally, the sandstones of the Burrows Member of the Red Jacket Formation have a gamma ray, spontaneous potential, and resistivity geophysical log signature that is distinctly different from those of the calcareous mudstones of the overlying Rierdon Formation. There is, however, a problem in those areas where the uppermost *Gryphaea*-bearing sandstone is uncemented or even absent, and where the underlying unit B of the Burrows Member is not quite as sandy as it should be. In these cases, distinguishing the top of the Red Jacket Formation from the calcareous mudstones of the overlying Rierdon Formation on logs becomes a major problem. Only careful observations in cores from nearby boreholes and meticulous log correlations from one well to the next may allow resolution of this problem.

Thickness and Distribution

The areal distribution of the Red Jacket Formation is shown as the cross-hatched area in Figure 4b (in pocket). It extends eastward of the cut-off line to the Manitoba border and southward to the North Dakota border. To the north it reaches as far as the eroded edge of the Jurassic.

The Red Jacket Formation thickens from zero at its northern erosional edge (erosional edge of the total Jurassic) to an approximate average of some 70 to 75 m in the Wapella-Moosomin area. Local thickness variations of up to 90 m were reported by Kreis (1988), and a maximum thickness of 107.1 m is reached in the Chevron Clayridge 8-10-17-1 well (Lsd. 8-10-17-1W2). This local thickening is suspected to be related to syndepositional solutioning of the underlying Middle Devonian Prairie Evaporite.

The Red Jacket Formation was severely affected by erosion during the Late Jurassic and/or Early Cretaceous in the north half of the Wapella-Moosomin area. The areas affected are outlined by the erosional edge of the Rierdon Shale (Figure 8, in pocket). Beyond this edge, all of the Rierdon Shale has been eroded and the underlying, uppermost strata of the Red Jacket Formation have been incised to variable depths and stratigraphic horizons.

Age and Correlation

As mentioned earlier, the Red Jacket sequence correlates with the Shaunavon Formation and the upper member of the Gravelbourg Formation of southwestern Saskatchewan (Figure 14). This implies that it is also correlative with the Bowes, Firemoon Limestone, and Tampico Members of the Piper Formation of northeastern Montana and northwestern North Dakota (Imlay, 1980). Kreis (1988) also suggested an equivalency with the Reston and, possibly, some portion of the Melita Formation of Manitoba.

Imlay (1980) assigned the Gravelbourg and the lower member of the Shaunavon Formation of southwestern Saskatchewan a Middle to Late Bajocian age, and placed the upper member of the Shaunavon Formation in the Early Bathonian. By implication, the Red Jacket Formation therefore is Late Bajocian to Early Bathonian in age.

Rocanville Member of Red Jacket Formation

Lithology

The division of the Rocanville Member into the units Rocanville "A", "B", and "C" in this report differs somewhat from that proposed by Kreis (1988 and 1989).

Rocanville "A" of the Rocanville Member occurs between approximately 759.6 to 760.5 m (2492-2495 ft) below K.B. in the reference well for the Rocanville Member Tide Water Wapella No. 6-33 (Figure 21). In the same borehole, Rocanville "B" occupies the section from approximately 737.6 to 759.6 m (2420-2492 ft) and Rocanville "C" is placed between approximately 731.5 to 737.6 m (2400-2420 ft), (for details see core description in Appendix C.3).

In the Wapella-Moosomin area, Rocanville "A" is composed of an olive-grey, sandy (up to 30 percent very fine-grained clear quartz) siltstone with abundant mica and carbonaceous detritus, and trace amounts of pyrite. This lithology is very similar to the siltstone in the thicker section of Rocanville "A" observed in a core taken from the Pondex Pat Parkman 5-22-10-1 (Lsd. 5-22-10-1W2) well immediately south of the Wapella-Moosomin area (Figure 11, in pocket; Photo 5).

Rocanville "B" comprises sandstone, dolomitic mudstone, dolomitic limestone and dolostone. The lower half of Rocanville "B" is commonly characterized by a subunit of stacked, sheet-like bodies of clear quartz sandstone which blanket most of the Wapella-Moosomin area. In some wells, these sandstones overlie a thin remnant of Rocanville "A", but most commonly are found disconformably overlying an argillaceous limestone bed at the top of the underlying unit B of the lower Gravelbourg. This limestone appears to form an erosion-resistive bench over much of the area and is readily recognizable in the cross-section through the Wapella Field (Figure 15, in pocket). Elsewhere, the limestone is eroded and the resulting lows are infilled by the basal sandstones of Rocanville "B" (Figure 22).

The sandstone subunit at the base of Rocanville "B" is generally composed of moderately to well sorted, subangular to subrounded, clear quartz which ranges in grain size from very fine to medium, with fine grained being the most common. Cementation by calcite is common but is highly variable from well to well.

Mica and pyrite are the only two common accessory minerals found in the sandstones and siltstones of Rocanville "B". Large mica flakes (up to 1.5 mm across) are present in minor to locally extremely abundant amounts (up to 30 percent), while pyrite is found in trace to minor amounts only. The mica flakes most commonly occur in silty and argillaceous laminations, but also occur in lesser amounts intermixed with the bulk of the quartzose sandstone. Locally, the micas are partially to completely glauconitized (Photo 6). Pyrite is commonly disseminated but also forms large pyrite-cemented nodules up to 2 cm across within the sandstone. Euhedral pyrite crystals up to 0.5 cm across occur in argillaceous limestone and calcareous mudstone interbeds.

Sedimentary structures are barely visible in these sandstones, which tend to be either massive, or weakly laminated with argillaceous and silty material. Low-angle and high-angle planar cross-stratification (Photo 7), and rare small-scale current ripple bedding were observed in a few places.

The sandstones in the lower half of Rocanville "B" are typically interbedded with siltstones, mudstones, argillaceous dolomitic limestones and rarely dolostone. The contacts between these interbeds are commonly sharply defined. The siltstone and mudstone interbeds range from very light grey to olive-grey, whereas the dolostone tends to be yellowish-grey to pale yellowish-brown. The mudstones are most commonly calcareous but can be non-calcareous or dolomitic.

These stacked sandstones are presently known only from the Wapella Field area, since they are cored only in that region. One other core through the lower part of Rocanville "B" in which there is an apparently equivalent basal sandstone is in the Pondex Pat Parkman 5-22-10-1 (Lsd. 5-22-10-1W2) well to the south. In this borehole, the lowermost 6 m of this sandstone is composed of a yellowish-orange to greyish-orange, moderately to poorly sorted, subrounded to well rounded, fine- to coarse-grained clear quartz with abundant silt and mica. This sandstone body is dominated by high-angle planar cross-stratification (up to 30°), shows numerous truncated surfaces and a sharp erosional basal contact with the underlying Rocanville "A" (Photo 5). It grades up into fine to medium-grained, clear quartz sandstone and eventually into very fine-grained quartzose sandstone. Small-scale current ripples and massive, featureless bedforms dominate this uppermost portion of the sandstone body, and closely resemble the sandstones in cores from the lower half of Rocanville "B " in the Wapella Field.

The upper half of Rocanville "B" is dominated by variegated, dolomitic mudstones, very fine- to fine-

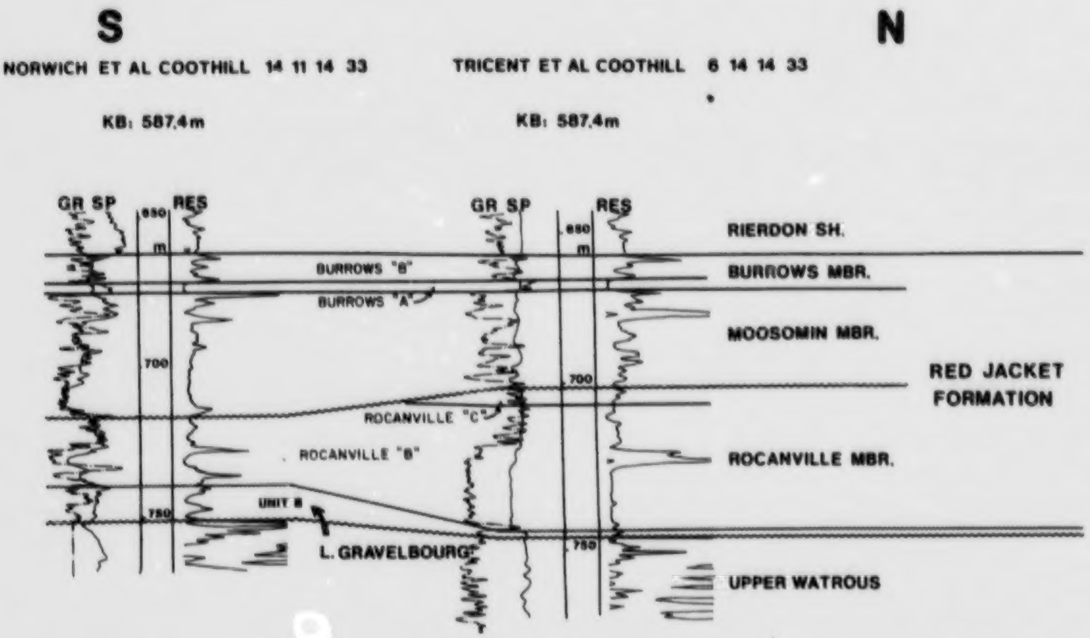


Figure 22 - Cross-section showing erosion and infilling of unit B of the lower member of the Gravelbourg by Rocanville "B" strata.

grained sandstones, siltstones and minor argillaceous dolostones. In thin section, some of the sandstones appear to be glauconitic locally, but much of the glauconite matrix has altered to a brownish coloured mineral that may be chamosite (Photo 8). Rare pellet-like masses similar to those in Photo 9 are also found. The variegated colouration (Photo 10) ranges from dark reddish-brown through to greyish-orange and greenish-grey. Greenish-grey appears to be the original colour of the rock. Dolostone interbeds tend not to show variegation and are typically various shades of yellowish-grey to pale yellowish-brown.

The mudstones in the upper half of Rocanville "B" tend to be dolomitic to calcareous and are locally quite sandy (up to 30 percent very fine-grained clear quartz). Typically, they are hard and exhibit blocky to slabby partings, are slickensided in places, and appear to be dessicated locally (Photo 11 and 12). The mudstones commonly grade into siltstones, very fine- to fine-grained sandstones and argillaceous, dolomitic limestones and dolostones.

Sandstone interbeds in the upper half of Rocanville "B" show low-angle cross-stratification and small-scale current ripple bedding.

In the CNW Wapella 14-2-15-1 well (Lsd. 14-2-15-1W2), a 2 m-thick zone of argillaceous, very fine- to fine-grained sandstone at the top of Rocanville "B" exhibits compactionally folded, calcitic, tubular-shaped, structures which appear to be rootlet molds (?) (Photo 13). This phenomenon possibly formed as a caliche; i.e. related to weathering during exposure (Christopher, pers. comm., 1989).

Rocanville "C" is characterized by a thin (typically less than 10 m) sequence of interbedded sandstone, siltstone, mudstone and sandy, variably fossiliferous lithographic limestone. Interbedded and interlaminated sandstone and siltstone dominate this unit. The sandstone tends to be very fine grained, but grades up to fine grained locally. It is silty, micaceous, and in places argillaceous and glauconitic. The glauconite occurs as pellet-like masses and in a few places as small irregular masses. They are medium to coarse grained and are commonly zoned with a brownish core (Photo 9) which may be chamosite (?). The siltstones are also micaceous. The minor mudstone interbeds are greenish-grey, hard, generally very calcareous, show slabby to blocky partings, and commonly grade into, and become interlaminated with, siltstone and very fine-grained sandstone beds.

A thin (less than 2 m) but well-developed interbed of oolitic and bioclastic limestone at or near the top of Rocanville "C" was found in a number of wells in and around the Wapella Field. This limestone component is highly distinctive and sets Rocanville "C" apart from all overlying and underlying strata. It is composed of a variety of fossil debris, oolitic grains and varying amounts of quartz (locally up to 30 percent) in an essentially lithographic limestone matrix (Photo 14). In the Wapella Field and region, this limestone unit forms a bench which appears to have been relatively resistant to erosion below the sub-Moosomin disconformity, and is therefore only locally breached in this area (Figure 15, in pocket).

It is noteworthy that Rocanville "C" is only readily recognized in cores within the Wapella-Moosomin area. It can only be distinguished from Rocanville "B" on a geophysical log when lithographic limestone interbeds are present and show up as thin highly resistive beds, as in the Wapella Field (Figure 15, in pocket).

Paleontology

No megafossils were found in Rocanville "A", but a variety of palynomorphs were identified in a single sample taken from a depth of 760.2 m in the Tidewater Wapella No. 6-33 well. The palynomorph assemblage is exclusively of terrestrial species, three of which are included in the palynological assemblage described by Pocock (1972) from the upper member of the Gravelbourg Formation of southern Saskatchewan. They are: *Calamospora mesozoica*, *Concavissimisporites southeyensis* and *Protopicea exilioides*. *Classopollis itunensis* is also found in both Rocanville "A" and in the upper member of the Gravelbourg Formation, but was not included in the palynological assemblage for the upper Gravelbourg by Pocock. Three other species belonging to the upper Gravelbourg palynological assemblage mentioned by Kreis (1989), and which were also found in the single sample of Rocanville "A" are: *Deltoidospora harrisii*, *Podocarpidites Wapellaensis* and *Triangulopsis discoidalis* (Table 1). The similarity of palynological assemblages for Rocanville "A" and the upper member of the Gravelbourg Formation supports their correlation.

A single sample taken for microfossil identification from Rocanville "A" in the Tidewater Wapella No. 6-33 well between 760.4-760.5 m yielded an abundance of the freshwater ostracode *Darwinula oblonga*, a long-ranging form. The palynomorphs and this ostracode species point to a freshwater terrestrial environment of deposition, but they are not useful as age determinators.

In Rocanville "B", a few small fish (?) teeth (less than 2 mm long), rare bone fragments (less than 0.5 cm long), as well as a few poorly preserved pelecypod and gastropod shell fragments are the only indications of megafossils. However, a variety of poorly preserved palynomorphs and a few microfossils were tentatively identified from this unit. The terrestrial species *Pityosporites divulgatus* and the "marine" species *Tasmanites suevicus* are two palynomorphs found in both Rocanville "B" in this study and in the Lower Member of the Shaunavon Formation of southern Saskatchewan by Pocock (1972). Other marine microfossils identified in Rocanville "B" include: the dinoflagellate *Leiosphaeridia hyalina* and some indeterminate (i.e. badly corroded) dinoflagellates were recovered from Rocanville "B".

A few poorly preserved specimens of the freshwater ostracodes *Darwinula oblonga* and *Limnocythere* sp. were also found in the few samples taken from Rocanville "B" in this study. The presence of both marine and terrestrial palynomorphs, and a few freshwater ostracodes point to a "near-shore" marginal marine environment of deposition.

The megafaunal assemblage found in Rocanville "C" is distinctive and composed of locally abundant pelecypods, a few small (less than 1 cm) gastropods, minor amounts of crinoid debris, and one coral. The pelecypod and gastropod species have not been identified; however, the crinoid ossicles appear to be derived from the genus *Pentacrinus*, and the coral (Photo 15) is identified as *Actinastrea* cf. *A hyatti* (Wells). Unfortunately, *Pentacrinus* ossicles have been recovered from many localities in the western interior of the United States and have little stratigraphic value other than suggesting a Jurassic age (Paterson, 1968). On the other hand, Imlay (1967, p.35) noted that almost all the corals found in the western interior of the United States have been recovered from Bajocian strata. The Lower Member of the Shaunavon Formation of southwestern Saskatchewan contains *Actinastrea* cf. *A. hyatti* (Wells), and was also assigned a Bajocian age by Paterson (1968). This supports the correlation of Rocanville "C" of the Rocanville Member with the Lower Shaunavon of southwestern and west-central Saskatchewan.

In this context it must be pointed out that the only specimens of *Actinastrea* cf. *A. hyatti* (Wells) from the Wapella-Moosomin area came from one well only: Aberford Wapella 12A-34-14-1 well (12-34-14-1W2). The corals are clearly abraded and were derived from the top of Rocanville "C". They were reworked and became incorporated in a basal bioclastic "coral" conglomerate of the overlying Moosomin "A" unit (base of Moosomin "A2" subunit; see also Figure 15, in pocket, and Photo 15). Interestingly, Paterson (1968) also reported the presence of derived *Actinastrea* cf. *A. hyatti* (Wells) specimens from the Lower Shaunavon in a basal conglomerate of the Upper Shaunavon in southwestern Saskatchewan. Such a coincidence makes sense considering the very compact nature of the coral skeletons. This similarity in contact relationship supports the correlation of Rocanville "C" of the Rocanville Member of the study area with the uppermost portion of the Lower Shaunavon Member of southwestern Saskatchewan.

The single sample from Rocanville "C" analyzed for palynological investigations came from the Tidewater Wapella No. 6-33 borehole. It yielded only a few very poorly preserved specimens of dinoflagellates (indeterminate) and trilete spores. Another sample taken from the same well and horizon, however, yielded four varieties of marine ostracodes: *Pleurocythere* n. sp., *Paracypris* sp., *Procytheridea* sp. and *Cytheropteron* sp.

The presence of crinoid ossicles, coral, dinoflagellates and a number of marine ostracodes suggests a "marine" environment of deposition for Rocanville "C".

Member Boundaries

Top and base of the Rocanville Member was defined in the type section for the Red Jacket Formation between the depths 719.3 to 734.6 m, but a better reference section for that member is the Tide Water Wapella No. 6-33 well (Lsd. 6-33-14-1W2) between the depths 731.5 to 760.5 m. For details see Figure 21, and Appendix C.3 for core descriptions.

Only in this and two other boreholes does the lower contact of Rocanville "A" represent the true stratigraphic and lower boundary of the Red Jacket Formation (Figures 11 and 15, in pocket). A disconformity within the Rocanville Member near its base (apparently at the base of Rocanville "B") appears to truncate Rocanville "A" in nearly all of the wells in the Wapella-Moosomin area. In fact, it is only preserved as a thin (less than 1 m) remnant of strata in cores from three wells in the Wapella Field: Tidewater Wapella No. 6-33 (Lsd. 6-33-14-1W2), Tide Water Wapella No 16-33-14-1 (Lsd. 16-33-14-1W2), and Tide Water Earlswood Crown No 1-36 (Lsd. 1-36-14-1W2). The lower contact of the Red Jacket Formation is generally sharply defined on geophysical logs when Rocanville "B" comprises the base of the Rocanville Member (see Figures 11, 12, 15 and 23, in pocket). On the other hand, if a thin remnant of Rocanville "A" is present at the base of the Rocanville Member, it is difficult to separate on geophysical logs from overlying sandstone and siltstone beds of Rocanville "B", as well as the underlying interbedded sequence of argillaceous limestone and calcareous mudstone of unit B of the lower Gravelbourg. It is, however, readily recognizable in core on the basis of its non-calcareous, carbonaceous and micaceous nature. The cross-section in Figure 11 (in pocket) shows the truncation of Rocanville "A" in a northerly direction towards the study area.

Unfortunately, the basal contact of the Rocanville Member is often not preserved in cores within the study area and physical evidence of an erosional contact is therefore lacking. With respect to the upper contact of Rocanville "A", the best preserved contact showing an erosional disconformity between Rocanville "A" and "B" was observed in a core outside the study area, the Pondex Pat Parkman 5-22-10-1 well (Lsd. 5-22-10-1W2). In this core (see Figure 11, in pocket), micaceous, carbonaceous and sandy siltstone of Rocanville "A" is in sharp contact with an overlying moderately to poorly sorted, fine- to coarse-grained, cross-bedded sandstone of Rocanville "B" (Photo 5).

Another discontinuity exists within the Rocanville Member near its top in the Wapella-Moosomin area. Sandstones forming Rocanville "C" are in sharp erosional contact with the underlying sandstones and dolomitic mudstones of Rocanville "B" (Photo 16). There appears to be little removal of the underlying dolomitic mudstones of Rocanville "B", suggesting the hiatus between Rocanville "B" and "C" was of brief duration. Similar to Rocanville "A", Rocanville "C" is commonly missing in wells within the study area. The absence of Rocanville "C" is interpreted to be the result of erosion during the hiatus between the Rocanville and Moosomin Members.

The contact between the Rocanville and the overlying Moosomin Member is a sharply defined, upper boundary in the Wapella-Moosomin area. A number of cores show evidence of an erosional disconformity between these two members. Perhaps the best example is in the

CNW Wapella 6-2-15-1 well (Lsd. 6-2-15-1W2) where a poorly sorted, fine to coarse-grained sandstone at the base of Moosomin "A" is in sharp contact with underlying interbedded sandstone, siltstone, and dolostone of Rocanville "B" at a depth of 743.9 m (Photo 17). The lower 10 cm of this sandstone contain abundant siltstone pebbles identical to the siltstone of the underlying Rocanville "B" strongly suggesting that they were derived from it. The west to east cross-section in Figure 15 (in pocket) shows the incision of the Rocanville Member and subsequent infill by Moosomin "A1" of the Moosomin "A" unit. Note that Moosomin "A1" in the Aberford Wapella 8A-34-14-1 well (Lsd. 8A-34-14-1W2) is coincident with the Wapella-North Wapella paleo-valley indicated on the isopach map of the Rocanville Member (Figure 24, in pocket).

Thickness and Distribution

The thickness and distribution of Rocanville strata in the Wapella-Moosomin area is shown on the isopach map in Figure 24 (in pocket). The thickness of the member varies from 0 m in a few wells to a maximum observed thickness of approximately 72 m in the Cromer Valley Wapella 12A-36-14-1 borehole (Lsd. 12-36-14-1W2). The conspicuous variation in thickness, as well as the distribution of the Rocanville Member itself may be attributed to one or some combination of the following four factors:

1) A disconformity at the base of Rocanville "B" appears to have removed Rocanville "A" and deeply incised unit B of the lower Gravelbourg. This is particularly true in the area centred around the wells Tricent *et al.* Coothill 6-14-14-33 (Lsd. 6-14-14-33W1) and CNW SRO Moosomin 11-8-13-32 (Lsd. 11-8-13-32W1). In both wells it appears that the thickening of the Rocanville is related to infilling of a possible channel by Rocanville "B" sediments (Figure 22). The channel is evident as a northeast-southwest isopach trend centred around these wells (Figure 24, in pocket).

2) Syndepositional collapse related to dissolution of the Devonian Prairie Evaporite may have caused some of the other thickness anomalies, particularly in the vicinity of the Cromer Valley Wapella 12A-36-14-1 (Lsd. 12-36-14-1W2), Chevron Clayridge 8-10-17-1 (Lsd. 8-10-17-1W2), Coho *et al.* Welwyn W 8-16-15-31 (Lsd. 8-16-15-31W1), Triton Rocanville 4-5-16-31 (Lsd. 4-5-16-31W1), and W H Hudson Riddle Rocanville 6-4 (Lsd. 6-4-16-31W1) wells. The greatest syndepositional thickening of the Rocanville Member appears to have occurred in the Cromer Valley Wapella 12A-36-14-1 borehole. There is considerable corroborating evidence to indicate that salt dissolution and the resulting collapse have played a major part in creating some of the anomalies traced and emphasized in Figure 24 (in pocket). To begin with, a combined isopach map of the Rocanville and Moosomin Members shows the thickness anomalies centred around the above mentioned localities, as well as in a few additional areas (Figure 25, in pocket). Perhaps, the most striking feature of this map is a general northeast to southwest trend of thickness anomalies which is coincident with or about parallel to the entire length of the Red Jacket-Rocanville paleo-valley shown in Figure 24 (in pocket). This relationship suggests that the paleo-valley was controlled, at least in part, by a number of sinkholes having a northeast to southwest orientation. A similar scenario is envisaged for the Wapella-North Wapella paleo-valley, although it is less obvious from the isopach data of Figure 25.

Christopher (1961, p. 59) had already described a broad northeast-southwest trend of "...regionally aligned depressions and sinks extending from the Rocanville field, through the Wapella field to the Tidewater-Imperial South Kisbey Crown No. 1 well,...", which he named the Rocanville-Torquay trend. He further suggested that the influence of this trend is demonstrated by the occurrence of a number of oilfields along its course: Rocanville Field (middle Bakken production); Wapella Field (Cretaceous and Jurassic production); Moose Valley, Parkman, Weyburn, Midale, Benson, Torquay and Oungre Fields (Mississippian production); Hummingbird Field (Ordovician production); and continuing into the Poplar Field (Ordovician production) in Roosevelt county, Montana.

One might speculate that the northeast-southwest trend of apparent solution-induced anomalies, on a local scale, in the Wapella-Moosomin area (Figure 25, in pocket), and on a more regional scale along the Rocanville-Torquay trend (see Christopher, 1961, p.60) may have been controlled by an underlying basement structural control. It is quite possible, therefore, that the Birdtail-Waskada Axis and Nelson River gravity trend (discussed later) may be tectonic features related to the Rocanville-Torquay trend.

3) Erosion producing the sub-Moosomin unconformity caused considerable topographic relief and thus markedly effected the thickness of the Rocanville Member. Figure 24 (in pocket) can be used, in a general way, as a paleogeographic map of the eroded Rocanville. Lithological evidence from cores and cross-section correlations suggests that most of the wells, which show a thinning of Rocanville strata, have been incised to a greater stratigraphic depth than the surrounding wells. For example, the Aberford Wapella 8A-34-14-1 well (Lsd. 8A-34-14-1W2) of cross-section C-C' in Figure 15 shows incision of the Rocanville Member and subsequent infill by subunit "A1" of Moosomin "A" of the Moosomin Member. This well is located in the Wapella-North Wapella paleo-valley. The cross-section D-D' in Figure 23 also shows a tentative correlation of Moosomin "A1" infilling the Red Jacket-Rocanville paleo-valley and the Fleming lowlands. Paleo-valleys, lowlands and highlands are readily recognizable in Figure 24 (in pocket) and are named after local communities.

The erosional unconformity at the top of the Rocanville reaches a maximum stratigraphic relief of some 30 m in both the Wapella-North Wapella and Red Jacket-Rocanville paleo-valleys (see Figures 15, 23 and 24, in pocket). The 20 m isopach contour of the Rocanville Member has been arbitrarily chosen as the approximate value separating highlands (greater than 20 m) and lowlands (less than 20 m) on the Rocanville isopach map. This value appears to provide the best definition of the areas in which the greatest incision has occurred.

4) In places, some of the Rocanville was removed during erosion which produced the sub-Cretaceous unconformity. In fact, in the northeast quadrant of the study area, the entire Rocanville Member was removed (Figure 24, in pocket) and the Mannville Formation unconformably overlies the Mississippian Souris Valley Beds.

Recognition of the Rocanville Member is limited to the area of study because of a paucity of cores outside this area, and a general lack of contrast in geophysical log signatures between it and the overlying Moosomin Member.

As previously noted, Rocanville "A" is thinly developed (less than 1 m) and often absent in the study area. Likewise, Rocanville "C" is a thin unit (typically less than 10 m). Thus, the majority of the Rocanville Member strata present in the Wapella-Moosomin area belongs to Rocanville "B".

Age and Correlation

General lithological and palynological similarities between the upper Gravelbourg and Rocanville "A" support their correlation (see Figure 11, in pocket). By implication, Rocanville "A" is also correlative with the Tampico Shale (lower Piper Formation) of northeastern Montana and northwestern North Dakota which was placed in the Middle to Upper Bajocian time by Imlay (1980). It is tentatively correlated with either the middle portion of the Reston Formation of Manitoba as conceived by Stott (1955), or the lowermost portion of the Melita Formation as defined by Francis (1956) (see Figure 5).

The combined strata of Rocanville "B" and "C" is tentatively equated with the Lower Shaunavon (Figure 11, in pocket), which by implication makes them equivalent to the Firemoon Member of the Piper Formation of northeastern Montana and northwestern North Dakota and Late Bajocian in age (Imlay, 1980). Both units correlate with either the upper portion of the Reston or with the Melita Formation, depending on which stratigraphic scheme is used (see Figure 14).

On lithological and paleontological grounds one might be tempted to equate Rocanville "B" with unit 1, and Rocanville "C" with unit 2 of the Lower Shaunavon. Tracing units 1 and 2 on geophysical logs into the Wapella-Moosomin area is, however, a highly speculative undertaking due to the similarity of signatures produced by their similar lithologies. Furthermore, a lack of core outside of the study area precludes checking the correlation, and therefore, was not attempted on the accompanying cross-sections.

Moosomin Member of Red Jacket Formation

Moosomin "A" is composed of the strata between approximately 690.7 to 719.3 m (2266-2360 ft) depth below K.B. in the type section in the TW North Wapella Cr 14-22-15-1 well. In the same borehole, Moosomin "B" is located between approximately 675.2 to 690.7 m (2215-2266 ft) below K.B. Unfortunately, the contact between Moosomin "A" and "B" is not preserved or cannot be distinguished in the type section (see Appendix C.2 for core description). To facilitate description, Moosomin "A" is further divided into subunits "A1" and "A2". The top of Moosomin "A1" is taken to be at approximately 704.4 m (2311 ft) in this well. As mentioned earlier, Moosomin "A1" subunit infills the eroded paleotopography of the Rocanville Member which was developed during the hiatus at the end of Rocanville time (i.e. end of Lower Shaunavon time). It is therefore the oldest unit of the Moosomin Member in the Wapella-Moosomin area.

Moosomin "A" and "B", as defined here, differ slightly from units A and B of the Moosomin Member described previously by Kreis (1988 and 1989).

Lithology

Unfortunately, Moosomin "A1" is only cored in a few wells in the Wapella Field and North Wapella area. In these wells, this subunit is characterized by interbedded and interlaminated sandstone, siltstone, and mudstone. Contacts are commonly sharp between these lithologies. The sandstones range from very fine- to coarse-grained, but are most commonly fine grained. They also range from poorly sorted to well sorted, but are typically moderately sorted. They are composed of angular to subrounded, clear quartz grains with widely varying amounts of silt, mica, pyrite, carbonaceous detritus and argillaceous content. They are light olive-grey to yellowish-grey, and where oil stained, from pale yellowish-brown to dark yellowish-brown. Calcite cementation is highly variable in these sandstones.

In core, Moosomin "A1" sandstones are commonly massive but, in places, also show low- and high-angle planar cross-stratification and bipolar flow structures (Photo 18). Generally, the sandstones fine upwards into siltstones and mudstones. This trend is indicated by the bell-shaped signature of the spontaneous potential (SP) curve for Moosomin "A1" in the Aberford Wapella 8A-34-14-1 well (Lsd. 8-34-14-1W2) (Figure 15, in pocket).

Siltstones and mudstones in Moosomin "A1" vary from olive grey to medium grey and are generally non-calcareous. They commonly possess lenticular bedding and are interlaminated with very fine- to fine-grained sandstone (Photo 18). Carbonaceous detritus and mica are abundant in this unit (Photo 19). Large mica flakes (up to 1 mm across) are common, whereas carbonaceous material ranges from very fine-grained detritus to rare large, carbonized wood fragments spanning the entire cross-sectional surface of the core (i.e. 8 cm across). Disseminated pyrite is present in trace to minor amounts, and rare siderite nodules up to 6 cm across were observed in this unit (Photo 20). For details see Appendix C.4 for core description of Moosomin "A1" in CNW Wapella 6-2-15-1 well.

Moosomin "A2" has a gradational contact with Moosomin "A1", and it shares many of the lithological characteristics of Moosomin "A1". It differs from Moosomin "A1" in the following features: it tends to have less carbonaceous detritus, tends to be siltier and finer grained, has rare interbeds of argillaceous bioclastic limestone, and is locally glauconitic. Glauconitized pellet-like masses (fecal pellets ?) up to medium grain size are found in trace to locally abundant amounts in some sandstones in this subunit (see core description in Appendix C.3).

A rare argillaceous bioclastic interbed occurs near the base of Moosomin "A2" at a depth of approximately 693.4 m in the core from the Sohio North Wapella No. 11-13 well (Lsd. 11-13-15-1W2). The 55 cm thick, light olive-grey, dense bioclastic limestone interbed is sandy (up to 30 percent very fine-grained clear quartz) and argillaceous, and contains abundant pelecypod molds (of indeterminate genus) up to 3 cm across. It also contains abundant, disseminated, very fine-grained pyrite.

Sandstones in Moosomin "A2" are commonly interbedded and interlaminated with light olive-grey to olive-grey mudstones and siltstones. Small-scale wave- and current-ripple bedding (Photo 21) along with wispy, discontinuous laminations are the dominant sedimentary structures in this subunit. Climbing ripples also exist (Photo 22), as does low-angle planar cross-stratification.

As in Moosomin "A1", mica and pyrite are common accessory minerals in these sandstones. Calcite cementation in the "A2" sandstones is quite variable, but generally moderate, except for the top of the unit where it is commonly well-cemented with calcite and/or dolomite (Photo 23).

The generally finer-grained nature and better cementing of Moosomin "A2" commonly results in a weaker deflection of the spontaneous potential curve and a generally more resistive response on electric logs than that of Moosomin "A1". Unlike Moosomin "A1", there is no apparent tendency for the sandstones to fine-upwards, nor is there a tendency to coarsen-upwards (Figure 15, in pocket).

On the basis of lithology and stratigraphic position, Moosomin "A" is similar to unit "U1" of the Upper Shaunavon described by Christopher (1964) from southwestern Saskatchewan. This may imply that the apparent discontinuity between Moosomin "A" and "B" in the Wapella-Moosomin area may be coeval with the discontinuity postulated at the top of "U1" by Christopher in southwestern Saskatchewan.

Moosomin "B" is made up of interbedded and interlaminated sandstones, siltstones, mudstones and minor carbonates. The sandstones are yellowish-grey to very light grey, and light greenish-grey. They are most commonly moderately to well sorted, generally consist of very fine- to fine-grained, subangular to subrounded, clear quartz with varying amounts of silt and argillaceous material, and are variably cemented. Moosomin "B" shows a fining-upwards trend in the sequence (see wells number 1 to 3 on cross-section, Figure 15, in pocket). Mica and pyrite are common accessory minerals in the sandstones of this unit, occurring in trace to locally abundant amounts.

Lenticular, flaser and wavy bedding is common in Moosomin "B" sandstones particularly in the upper 5 to 10 m (approximately) of the unit (Photos 24 and 25). Bioturbation is normally intense in the same interval imparting a "burrow-mottled" texture to the sediments (Photo 26). The sandstones mainly show low-angle planar cross-stratification (Photo 27) and small-scale current-ripple bedding. Sharp contacts with indications of truncation of underlying beds are typical throughout the upper 5 to 10 m of the Moosomin "B" lithology in some wells (Photo 27 and 31).

Below this upper "zone", the Moosomin "B" sandstones commonly appear structureless, are less sorted, siltier, more argillaceous, and show thicker interbeds of sandstone, siltstone, mudstone and marlstone (i.e. argillaceous limestone). Individual trace fossils are rarely recognized in this portion of Moosomin "B", possibly as a result of intense bioturbation which has obliterated primary sedimentary structures (Photo 28).

Siltstones and mudstones in Moosomin "B" are typically shades of greenish-grey to dark greenish-grey. The mudstones are composed of swelling clays which are commonly weakly calcareous or dolomitic. Syneresis cracks occur in the upper 10 m or so of Moosomin "B" in some of the wells in the study area (Photo 29).

Rarely, Moosomin "B" contains thin units (less than 2 m) of argillaceous, sandy limestones, marlstones, coquina-rich and algal(?)-laminated, very fine-grained sandstone and siltstone in the lower half of the unit. The algal(?)-laminated beds commonly occur near the base of Moosomin "B" and have a highly distinctive "pinstriped" appearance (Photo 30).

A different Moosomin "B" sandstone unit was encountered in some wells in the Moosomin and North Wapella localities and in the Red Jacket Field. It is a very fine- to fine-grained, well-sorted sandstone, up to 15 m thick which generally fines upward. These sandstones are characterized by low- to high-angle planar (up to 30°) cross-stratification (Photo 31), and flaser and small-scale current ripple bedding. Bioturbation is rare.

Mudstone drapes are common in this particular sandstone (Photo 32), and mudstone pebbles and clasts are commonly found at the bottom of the unit (Photo 33). Typically, organic detritus of so-called "coffee ground" appearance defines laminae in this sandstone, indicating periods of slack water deposition (Photo 34).

These sandstone bodies all occur approximately 10 m below the top of Moosomin "B" (i.e. approximately 10 m below the shale marker of Burrows "A"), and all show a fining-upwards sequence. The spontaneous potential

(SP) curve in the Tricent *et al.* Moosomin 4-28-14-31 well in Figure 16 shows the fining-upward nature of this sandstone body. These same sandstone bodies also form the petroleum reservoirs in the North Wapella and Moosomin localities, and in the Red Jacket Field (Figure 1), and appear to be aligned in a northeast to southwest trend. Collectively, the spatial and temporal relationships of the sandstones to the contiguous strata as well as the sedimentary structures within the sandstones suggest that they are channel sandstone bodies. It is noteworthy, that, in the Moosomin locality these sandstones lie directly on trend with similar sandstone bodies in the Red Jacket Field to the southwest (Figure 1), perhaps indicating a continuation of the same channel.

On the basis of lithology and general stratigraphic position, Moosomin "B" is similar to unit "U2" and perhaps part of "U3" of the Upper Shaunavon sequence as defined by Christopher (1964) for southwestern Saskatchewan.

Paleontology

Rare pelecypod molds of indeterminate genus and fish remains (teeth and bones) are the only megafossils found so far in Moosomin "A". A diverse, terrestrially dominated palynological assemblage has been recovered from Moosomin "A" in seven samples taken from wells in and around the Wapella Field (see Table 1). All of the palynomorphs recovered came from Moosomin "A2", except for one sample of Moosomin "A1" from the CDN OXY Red Jacket W 6-25-13-1 well (Lsd. 6-25-13-1W2 at approximately 777.0 m below K.B.), which yielded a variety of terrestrial palynomorphs and a few specimens of the marine palynomorphs *Leiosphaeridia* and *Comasphaeridium* sp. Although there is a preponderance of terrestrial palynomorphs in Moosomin "A2", specimens of marine species like *Comasphaeridium* sp. A., *Leiosphaeridia hyalina*, *Rugidinium* sp., and *Solisphaeridium deflandrei* are also present. *Solisphaeridium deflandrei* is also a constituent of the palynological assemblage for the Upper Shaunavon as reported by Pocock (1972).

A few ostracode and foraminiferal species were recovered from Moosomin "A2". Although, *Ammodiscus* sp. and *Opthalmidium* sp. are the only Foraminifera recognized in Moosomin "A2" they typically occur *en masse*. Such monotypic to low diversity faunas indicate "stressed" environmental conditions. *Ammodiscus* sp. is a simple agglutinated species which could have lived in waters of lowered salinities, increased turbidity, or under slightly cooler temperatures (Brooke and Braun, 1972). *Opthalmidium* sp. is a simple miliolid which is known to dominate inshore areas with low-energy environments and lime-mud bottoms. A few brackish-water ostracodes belonging to the genus *Norcanolella*, and a few specimens belonging to the freshwater genera *Limnocythere* and *Darwinula* were also recovered from Moosomin "A2".

Samples taken from Moosomin "A1" for microfossil examination did not yield any recognizable microfossils.

The trace fossils from Moosomin "A" also show a low diversity but are locally abundant, suggesting a stressed environment (Ekdale *et al.*, 1984). *Planolites* and *Chondrites* are the only two ichnogenera recognized in heterolithic intervals containing mudstone, siltstone and sandstone (Photo 35).

In Moosomin "B", trace to minor amounts of fish scales, teeth, bones and poorly preserved, but locally abundant scattered pelecypod molds are the only megafossils found. Preservation of the pelecypods is extremely poor in the greenish-grey mudstone and marly interbeds of Moosomin "B"; however, in the Mark Moosomin 10-20-13-31 well (Lsd. 10-20-13-31W1), a single olive-grey mudstone interbed yielded numerous well-preserved fragments of gastropod shells, small (less than 0.5 cm) unidentified pelecypods and many well-preserved specimens of what appears to be the pelecypod *Thracia ? Montanaensis* (Meek)?. A similar abundance of pelecypod molds was noted in a superjacent bed of greenish-grey siltstone, but they were poorly preserved.

Moosomin "B" yielded an abundance of ostracodes including *Aparchitocythere* cf. *compressa*, *Darwinula oblonga*, *Limnocythere* sp., *Metacypris tenuimarginata*, and *Norcanolella parryi*. Collectively, these ostracodes indicate a freshwater to brackish-water environment (Brooke and Braun, 1972). Some sandstones and sandy mudstones within the upper 10 m of Moosomin "B" also yielded charophyte oogonia. *Darwinula*, *Limnocythere* and charophytes are freshwater indicators whereas the others are more brackish-water forms.

Moosomin "B" samples yielded a number of palynomorph species representing contributions from a wide range of terrestrial vegetation; however, a greater abundance of marine palynomorph species were recovered from Moosomin "B" than the few mentioned from "A". The assemblage includes several species of *Leiosphaeridia* and *Rugidinium*, as well as the marine palynomorphs *Solisphaeridium deflandrei* and *Tasmanites suevicus* (Table 1).

Botryococcus-type algae were found in the "pin-striped" laminated unit (Photo 30) in Moosomin "B" (Nambudiri, pers. comm., 1989). *Botryococcus* is considered to have lived in freshwater to brackish-water depositional environments (Traverse, 1988).

Three ichnofacies are found in Moosomin "B"; *Glossifungites*, *Skolithos*, and *Cruziana*. *Glossifungites* associations consist of a mixture of burrows and borings, with the borings being mainly attributed to bivalves (Pemberton, 1987), (Photo 36). The *Glossifungites* ichnofacies occurs in firm but unlithified substrates, which consist typically of dewatered muds (Pemberton and Frey, 1985) or incompletely cemented carbonates (Bromley, 1975). Since dewatering of muds and firm-substrate burrowing occur most commonly during subaerial exposure, these substrates and ichnofacies tend to develop intertidally or supratidally (Pemberton, 1987).

The *Skolithos* ichnofacies indicates relatively strong wave or current activity, typically resulting in a clean, well-sorted, loose or shifting substrate (Pemberton, 1987). *Glossifungites* and *Skolithos* ichnofacies are represented by the ichnogenera *Diplocraterion* in Moosomin "B", and are interpreted to be the traces of dwelling burrows of suspension feeders like polychaetes, echiuroids, and/or crustaceans (Pemberton, 1987). Some of the *Diplocraterion* burrows appear to be escape structures formed in an attempt by the burrow dweller to keep up with a rapid pace of sedimentation (Photo 37).

The *Cruziana* ichnofacies is most characteristic of sublittoral, poorly sorted and unconsolidated substrates found in estuaries, bays, lagoons, open continental shelves or epeiric seas. It may also occur in intertidal parts of low-energy intertidal flats, and on bars and beaches (Pemberton, 1987). The *Cruziana* ichnofacies is represented by the ichnogenera *Planolites* in Moosomin "B" (Photo 38). *Planolites* is interpreted to be a trace fossil of deposit-feeding activities of mobile endobionts (Pemberton, 1987).

The low diversity but abundance of the ichnofossil assemblage in Moosomin "B" suggests a "stressed" environment (Ekdale *et al.*, 1984). Ichnofossils are particularly well-preserved in the upper 5 to 10 m of Moosomin "B" where bioturbation is typical and commonly intense.

Member Boundaries

An erosional disconformity separates the Moosomin Member from the underlying Rocanville Member. Likewise, the top of the Moosomin Member shows a discontinuity with the overlying Burrows Member. In a number of wells in the study area, the discontinuity is represented by what appears to be a dessicated surface, with mud cracks developed in the underlying greenish-grey mudstone of Moosomin "B". The mud cracks are infilled with sandy, olive-grey mudstone of the overlying Burrows "A" (Photos 39 and 40). There is no sign of erosion so the discontinuity may represent a diastem.

Another minor discontinuity or diastem within the Moosomin sequence is used to separate the member into Moosomin "A" and "B"; however, the contact can only be traced with confidence throughout the Wapella Field where there is a relative abundance of cores and consistent log signature (Figure 15, in pocket). It is commonly defined by a clearly visible but somewhat irregular contact between a well-cemented dolomitic sandstone at the top of Moosomin "A" and an overlying varicoloured, dolomitic mudstone at the base of Moosomin "B". The sandstone of Moosomin "A" shows little sign of erosion at its top (Photo 23).

On geophysical well logs, the break between Moosomin "A" and "B" is only recognizable where the sandstone at the top of Moosomin "A" is well-cemented, as is the case in the Wapella Field. In all other regions, it is detectable only in core. The tracing of the boundary between Moosomin "A" and "B" within the study area, as shown on the cross-section in Figure 15 (in pocket) is therefore tentative. In the absence of core for corroborating evidence, the geophysical log picks can only be made arbitrarily.

In core, the break between Moosomin "A" and "B" is recognized as a colour, compositional and textural contrast between these units. Mudstones in Moosomin "B" are most commonly greenish-grey whereas the mudstones of Moosomin "A" are most commonly olive-grey. Carbonaceous detritus is rare in Moosomin "B", with the exception of the lower 5 m approximately, but is common in Moosomin "A". Texturally, the sandstones of Moosomin "B", again with the exception of the lower 5 m, tend to be less porous, more argillaceous, and are generally more calcite-cemented than the sandstones in Moosomin "A". An exception to these general characteristics is the well-sorted, highly porous and permeable channel-like sandstone bodies described earlier which locally punctuate the Moosomin "B" sequence.

Thickness and Distribution

As a unit, in the strictest sense, the Moosomin Member is confined to the study area where there is sufficient core to distinguish it from the underlying Rocanville Member. However, a tentative correlation of the Moosomin Member beyond this limited area has been attempted in Figure 11 (in pocket) where it is shown to correlate with the Upper Shaunavon with the exception of the uppermost part.

Figure 26 (in pocket) shows areas of thickened Moosomin strata which are coincident with the lowland and valley areas of the eroded Rocanville Member, as illustrated and emphasized in Figure 24 (in pocket). The 40 m contour line on the isopach map of the Moosomin is nearly coincident with the 20 m contour of the Rocanville Member over most of the study area. Areas greater than 40 m on the Moosomin isopach occupy almost all of the lowland areas and valleys shown on the Rocanville isopach map (compare Figures 24 and 26, in pocket).

Comparing the cross-sections in Figures 15 and 23 (in pocket) and the isopach map of the Rocanville Member in Figure 24 (in pocket), it can be seen that Moosomin "A1" appears to infill the lowlands of the eroded Rocanville Member. It also shows that Moosomin "A2" overlies subunit "A1" everywhere and oversteps across the paleohighlands formed on top of the eroded Rocanville surface.

There are three areas in which the contact between the Moosomin and the Burrows Member is missing below the sub-Cretaceous unconformity. They are located in the northwest, northeast and west-central portions of the Wapella-Moosomin area (see Figure 26, in pocket). The erosional subcrop on the Moosomin at this sub-Cretaceous unconformity lies between the dashed and solid line on this isopach map. In the area between these lines the Mannville Formation unconformably overlies the Moosomin Member.

The isopach map of the Moosomin Member shows a number of local areas of anomalous thickening (Figure

26, in pocket). Some of these are suspected to be of syndepositional origin induced by solution-collapse, for they appear to coincide with similar thickness anomalies of the isopach map of the Rocanville Member. For example, anomalous thickening in both units occurs in the vicinity of the Chevron Clayridge 8-10-17-1 well. In addition, the anomalously thick Moosomin sequence along a northeast to southwest trend which is coincident with the Red Jacket-Rocanville paleo-valley on the Rocanville isopach map (Figure 24, in pocket), may also be attributed to syndepositional thickening due to solution and collapse. Solution-collapse is supported by the coincidence of thickness anomalies on the same trend in the combined Moosomin/Rocanville isopach map (Figure 25, in pocket).

Age and Correlation

The Moosomin and overlying Burrows Members lie between the superjacent Rierdon Shale and the subjacent Rocanville Member of the Red Jacket Formation. Since Rocanville "B" and "C" are correlated with the Lower Member of the Shaunavon (Figure 11, in pocket), the intervening strata between the Rocanville Member and the Rierdon Shale are likely equivalent to the Upper Shaunavon of southwestern Saskatchewan.

Correlation of the Moosomin and Burrows Members with the Upper Shaunavon is based on log correlations, similarities in their lithologies and, to some degree, on similarities in their palynological assemblages (see Table 1).

The Upper Shaunavon is believed to be Bathonian in age so the same age may be applied to the Moosomin and Burrows Members (Figure 14).

Burrows Member of Red Jacket Formation

Lithology

Burrows "A" is a medium to dark grey, weakly calcareous claystone and mudstone unit (Photo 41). It is commonly interlaminated with micaceous siltstone and very fine-grained, clear quartz sandstone over the lower 30 to 40 cm of the unit. As noted previously, material from Burrows "A" is commonly seen infilling mud cracks in the underlying mudstone of Moosomin "B" (Photos 39, 40 and 41). In some wells such as in Tricent *et al.* Red Jacket 12-4-14-32 well (Lsd. 12-4-14-32W1), the sandy infilling material often contains minor to abundant amounts of well-worn bone fragments.

This unit is also characterized by rare occurrences of 2 to 3 mm thick interlaminations containing extremely abundant, small pelecypod molds (less than 1 cm across) of what are tentatively identified as *Pleuromya simplex* (?) and *P. oblongata* (?). Large pyrite masses (up to 8 cm across) or nodules are also present but are rare.

Burrows "A" is remarkably uniform in its thickness, ranging between approximately 2.5 to 3.2 m throughout the study area. An exception to this uniformity is found in the Dome *et al.* Moosomin 5-25-14-31 well (Lsd. 5-25-14-31W2) where Burrows "A" does not appear to be present. Instead, a thickened Moosomin "B" section is recognized on geophysical logs in its place. The mudstones belonging to Burrows "A" are the same strata commonly referred to by industry geologists as either the "Jurassic Shale Marker" or the "Shaunavon Shale Marker". It is indeed the most ubiquitous and dependable marker unit in the Jurassic section of the entire Wapella-Moosomin and conterminous areas.

Invariably, the top of Burrows "A" grades up into lenticularly bedded and bioturbated, greenish-grey mudstones and siltstones, and very light grey sandstones of the overlying Burrows "B". The mudstones of Burrows "B" are composed of weakly- to strongly-swelling clays which are commonly calcareous. The sandstones are typically calcite-cemented, moderately to well sorted, and comprise subangular to subrounded, very fine- to fine-grained clear quartz, with minor to locally abundant amounts of mica and pyrite. The pyrite commonly occurs as nodules or masses which effectively cement the sandstone over areas up to 5 cm across. Some interbeds have numerous well-worn pelecypods, and in the Tricent *et al.* Red Jacket 12-4-14-32 well (Lsd. 12-4-14-32W1) there is a bed of well-worn pelecypods and oncolites (Photo 42) at a depth of 658.6 m.

Intense bioturbation of sandstone and mudstone is very common in this unit, imparting the same distinctive "burrow-mottled" texture which is virtually identical to that observed in the upper 10 m or so of Moosomin "B" (Photo 26).

Paleontology

The pelecypods *Peuromya simplex* (?) and *P. oblongata* (?) dominate the megafaunal assemblage observable in core from Burrows "A". Fish (?) teeth and bones are the only other megafaunal elements found.

Microfossil samples yielded an abundance of the primitive foraminifers *Ammodiscus* sp. and *Opthalmidium* sp., which noted earlier, are thought to be indicative of relatively low energy, brackish-water to marginal marine environmental conditions.

Dinoflagellates form the dominant component in the palynomorph assemblage for Burrows "A". The most common types are Gonyaulacacean dinoflagellates which suggest the sediments were deposited in relatively open marine conditions (Williams, 1978). However, a variety of terrestrial palynomorphs are also present in moderate abundance (Table 1). Traverse (1988) suggested that spores and pollen, derived from continental vegetation are found in both continental and marine deposits (excluding deep sea sediments deposited at depths greater than 3,000 m) but their abundance gradually decreases towards open water.

The megafaunal assemblage of Burrows "B" consists of locally abundant but poorly preserved pelecypod molds (indeterminate?), fish bones, teeth and scales, and locally abundant charophyte oogonia. The charophyte oogonia generally occur in abundance in a single sandstone interbed and appear to be slightly worn, suggesting transport and subsequent incorporation in the sandy layer.

Two genera of ostracodes were recovered from Burrows "B": *Metacypris* cf. *tenuimarginata* and *Darwinula oblonga*. *Metacypris* cf. *tenuimarginata* suggests a freshwater to brackish-water depositional environment, whereas *Darwinula oblonga* is a typical freshwater form (Brooke and Braun, 1972).

The ichnofacies *Cruziana* and *Skolithos* are represented respectively by the ichnogenera *Diplocraterion* and *Planolites*, and are virtually identical in appearance to those found in the upper 10 m approximately of Moosomin "B" (Photos 37 and 38).

No palynomorphs were found in the single sample taken from Burrows "B" of the CNW Red Jacket 8-5-14-32 well.

Member Boundaries

The Burrows Member itself is divided into two informal units, Burrows "A" and Burrows "B". As noted earlier, mud cracks at the top of Moosomin "B" are infilled by sandy and argillaceous material found in the base of Burrows "A" (Photos 39, 40 and 41). The base of the member is thus easy to detect.

At its upper contact, the medium grey to dark grey claystone of Burrows "A" grades over a short distance into interbedded greenish-grey mudstone and light grey to light greenish-grey very fine- to fine-grained sandstones of Burrows "B". The upper boundary of Burrows "B" coincides with the top of the Red Jacket Formation.

Thickness and Distribution

Burrows "A" and "B" are recognized throughout the Wapella-Moosomin area (Figure 27, in pocket), and for a considerable distance beyond this region in southeastern Saskatchewan (Figures 11 and 12, in pocket) and into Manitoba (Figure 23, in pocket). The isopach map of the Burrows Member shows a relatively uniform thickness (between 7 and 12 m) of Burrows strata in nearly all of the wells (Figure 27, in pocket). There appears to have been little incision into the Burrows Member due to the disconformity at the base of the Rierdon Shale. Three smaller areas do show removal of Burrows strata below the sub-Cretaceous unconformity; in the northwest, northeast and west-central portions of the study area (Figure 27, in pocket).

Age and Correlation

The Burrows and the Moosomin Member appear to be the stratigraphic equivalents of the upper member of the Shaunavon Formation of southwestern Saskatchewan. This implies a Bathonian age for these units (Figure 14).

Based on the lithological characteristics and stratigraphic position of the Burrows Member, it is likely that it also represents the stratigraphic equivalent of unit "U3" and, perhaps, part of "U2" of the Lower Shaunavon described by Christopher (1964) for southwestern Saskatchewan.

Depositional History of the Wapella-Moosomin Area

In this chapter, an attempt is made to summarize the depositional history of the Triassic-Jurassic section of the Wapella-Moosomin area, particularly with respect to the Middle Jurassic strata of the Red Jacket Formation. The relative paucity and highly uneven distribution of boreholes, and relative scarcity of cores in the study area, precludes the construction of detailed sedimentological models for much of the strata investigated. However, sufficient information is available to attempt a broad reconstruction of the paleo-environments and depositional settings.

The Watrous Formation

Watrous Formation - Lower Member

The lack of fossils in the Triassic-Jurassic (?) red beds of the lower member of the Watrous Formation precludes a firm age assignment, but also a better understanding of the depositional setting of this unit throughout southern Saskatchewan. Published interpretations have been vague and tentative, at best, and rarely go beyond generalities. Earlier Canadian authors commonly interpreted the lower Watrous as marking the beginning of the Middle Jurassic marine succession, but few of them committed themselves to either a marine or continental model.

In general, the lithological and geophysical log characteristics of the lower Watrous are correlatable and show a remarkable regional continuity (Barchyn, 1982). This suggests that the lower Watrous was possibly deposited in an overall marine environment. The palynological evidence evaluated by Pocock (1972) falls in line, for he envisaged a marine depositional environment which was proximal to a dry coastline which in turn, was flanked by a desert. Yet, the ubiquitous reddish-brown colouration strongly suggests that these sediments were subaerially exposed and heavily oxidized. Their anhydritic nature furthermore indicates that highly restricted and evaporitic conditions were also aspects of the early Watrous depositional environment. The common occurrence of pitted and frosted quartz grains "floating" in a finer-grained matrix suggests wind transport from nearby eolian deposits.

It is possible that deposition largely occurred in a very shallow, restricted marine setting interrupted by periods of emergence which resulted in reworking of the sediments in an oxidizing continental setting. Barchyn's (1982) postulated model of sedimentation in extensive mud flats with playa lakes, and within an overall and frequently changing continental-marginal marine setting, is a likely depositional model for the lower Watrous.

Watrous Formation - Upper Member

The conditions that resulted in the formation of the red beds of the lower Watrous did not prevail throughout all of the Watrous and the upper strata of the Watrous were deposited in a somewhat different environmental setting. The presence of interbedded anhydrite, dolomite, and dolomitic mudstone clearly indicates a less restricted marine setting for the upper Watrous relative to the lower Watrous. The recovery of sixteen terrestrial and four marine species of palynomorphs by Pocock (1972) supports this interpretation.

It was noted earlier that the evaporitic upper Watrous increases in thickness at the apparent expense of the overlying unit A of the lower Gravelbourg in southeastern Saskatchewan (Figure 4b, in pocket). This implies that evaporitic conditions persisted in southeastern Saskatchewan while coeval dolomitic limestones of the lower Gravelbourg were being deposited further to the west.

The presence of thin beds of fine-grained quartzose sandstone and scattered grains of clear quartz near the top of the upper Watrous in some wells in southeastern Saskatchewan would appear to indicate proximity to one or more terrestrial sources in this region.

The upper Watrous oversteps the lower Watrous in a northeasterly direction in the Wapella-Moosomin area (Figure 13, in pocket), suggesting an outward expansion of the Williston Basin.

The Gravelbourg Formation

Gravelbourg Formation - Lower Member

The lower Gravelbourg is divided into two lithological units, A and B, which are separated by an unconformity that can be traced in both southwestern and southeastern Saskatchewan (Figure 4b, in pocket).

Upper Watrous deposition was followed by deposition of unit A of the lower Gravelbourg. The interbedded anhydrite, dolomite and dolomitic mudstones of the upper Watrous grade up into dolomites and argillaceous dolomitic limestones of unit A of the lower Gravelbourg. Locally, unit A has interbeds of oolite and algal-laminated dolomitic limestone. These lithologies indicate a less restricted marine depositional environment for unit A than for the upper Watrous and therefore suggest an overall expansion of the marine influences.

Although the paleo-environmental setting of the palynological assemblage of unit A (Table 1) cannot be fully reconstructed, the presence of only a few species of acritarchs and the absence of microforaminifera indicate some restrictions in this apparent marine environment and probable shallow-water conditions.

Deposition of unit A was abruptly terminated and is marked by a disconformity in both southwestern and southeastern Saskatchewan. The disconformity is indicated by a weathered zone of dolomite with abundant chalcedonic chert (Photo 1), and rare euhedral bipyramidal crystals of secondary quartz. It is likely that unit A overstepped upper Watrous sediments at one time in the study area, but was subsequently eroded back to its present limit (Figures 4b, 7, 11, 12 and 15, in pocket).

In the Wapella-Moosomin area, the interbedded calcareous mudstone and argillaceous limestone of unit B of the lower Gravelbourg Formation overstep unit A in a northeasterly direction (Figures 7, 11 and 12, in pocket). The oolitic, peloidal, bioclastic and glauconitic nature of some of the limestones in this unit strongly suggests a marine depositional environment for this unit. A marine setting is also supported by an abundance of microforaminifera in unit B (Kybett and Nambudiri, 1989). The poor preservation of palynomorphs in this unit is likely the result of slow deposition in a marine environment of high pH - conditions considered by Traverse (1988) to be corrosive to palynomorphs.

The presence of "thin-shelled" pelecypods (*Modiolus* ?), a few specimens of typical freshwater species of ostracodes like *Limnocythere* and *Darwinula* and the brackish-water *Norcanollela* in some wells suggest waters of reduced salinities, at least in places and at certain times. Perhaps the influence of rivers with high rates of discharge, or embayments with poor communication to normal marine waters, or both, may explain these occurrences. Pocock's (1972) suggestion that climatic conditions during lower Gravelbourg deposition were less arid than during upper Watrous deposition implies a greater contribution of fresh meteoric waters to the depositional system during lower Gravelbourg sedimentation. This could also account for a reduction in salinities in marginal areas of the transgressing sea.

Alternatively, it is possible that some, if not all, freshwater specimens were transported by rivers and deposited in the marine environment along the coastal margin. In this case, marine influences were more pervasive than would be the case in the other scenario.

In the Wapella-Moosomin area, the sandy bioclastic limestone interbeds in the lower half of unit B commonly develop into anomalously thick discontinuous bodies showing graded bedding, low to high-angle cross-stratification and numerous truncation surfaces (Photo 3). These sedimentary structures indicate fluctuating but generally high energy conditions - conditions which one might expect in an area of shoaling. Unfortunately, the poor distribution of control points in areas where these sandy bioclastic limestone bodies are thickest, such as in the Red Jacket Field, does not permit the accurate delineation of their geometry. Nevertheless, based on their lithological and sedimentological characteristics, these sandy limestone beds are interpreted to be near-shore bars that accumulated in a somewhat shallow water environment. The presence of glauconite in the sandy limestones supports a marine interpretation following Greensmith (1978) who suggests that glauconite commonly forms on the continental shelf in many parts of the world today at depths between 30 to 500 m.

The Red Jacket Formation

Rocanville Member

Lithological and palynological evidence for Rocanville "A" suggests a shift to an environment with considerably less marine influence than unit B of the lower Gravelbourg. Lithologically, Rocanville "A" is characterized by interbedded and interlaminated very fine- to fine-grained sandstone and sandy, noncalcareous, micaceous and carbonaceous siltstone and minor mud-stone. Unlike unit B of the lower Gravelbourg, however, marine indicators such as oolites, peloidal material, and glauconite are not present in Rocanville "A".

Rocanville "A" is characterized by terrestrial palynomorph species, whereas unit B of the lower Gravelbourg has more marine species. In addition, the contact between both units is sharply delineated, perhaps representing a diastem, and explaining the rapid change-over.

Pocock's (1972) assertion that the upper Gravelbourg was probably deposited in a near-shore coastal marine environment backed by extensive swamps is confirmed by the abundance of terrestrial palynomorphs, together with ostracode and foraminiferal species suggestive of lower salinities, and by the presence of some marine palynomorphs. Similarly, Rocanville "A" contains abundant terrestrial palynomorphs and freshwater ostracodes (e.g. *Darwinula*); however, no marine species were recovered from the single sample taken. This paleontological evidence suggests that Rocanville "A" may have been deposited in a more "landward" depositional environment in the Wapella-Moosomin area than the upper Gravelbourg to the southwest. The lack of marine species in only one palynological sample does not necessarily exclude the possibility of a near-shore marine depositional setting for this unit.

The olive-grey colour of the mudstone and siltstone of Rocanville "A" unit, plus the presence of very fine-grained disseminated pyrite and rare pyrite nodules, and preservation of abundant carbonaceous detritus, collectively suggest that Rocanville "A" was deposited under somewhat reducing conditions. Apparently, these reducing conditions in Rocanville "A" affected the underlying strata of unit B of the lower Gravelbourg, causing widespread pyritization at or near its upper contact.

Therefore, on the basis of the presently available lithological and paleontological data, Rocanville "A" is tentatively interpreted to have been deposited under reducing conditions in a continental to near-shore marine environment in the Wapella-Moosomin area. This writer furthermore agrees with Pocock (1972) that the continental environment was likely dominated by extensive swamps bordering an inland sea, perhaps within an inland coastal plain.

A disconformity appears to exist between Rocanville "A" and Rocanville "B" in the Wapella-Moosomin area. Immediately overlying this disconformity are stacked, sheet-like bodies of sandstone at the base of Rocanville "B". These sandstones are composed of very fine- to medium-grained, moderately to well-sorted, subangular to subrounded, clear quartz. They blanket most of the study area becoming thicker in a northerly and easterly direction (Figures 11, 12, 15 and 23, in pocket), possibly indicating proximity to sand sources in those directions.

The low-angle planar cross-stratification, small-scale current ripples and massive bedforms, together with the widespread nature of the basal sandstones of Rocanville "B" suggest that they may be a stacked sequence of near-shore marine shelf sands and possibly relict beach deposits. The sharp nature of the contacts between interbeds in these sandstones indicates rapid shifts in energy conditions - conditions one would expect in a beach to near-shore shelf environment.

The presence of glauconitized mica flakes in some of the sheet-like sandstone bodies in the lower half of Rocanville "B" also suggest a marine origin (Photo 6), a deduction further supported by the occurrence of marine palynomorphs. Although not exclusive to the marine environment, the collective occurrence of carbonate interbeds, fish remains (i.e. teeth and bones), fragments of pelecypod shells and rare gastropod shells also appears to support such an interpretation. The relative abundance of terrestrial palynomorphs compared to marine palynomorphs in Rocanville "B", suggests a more "near-shore" marine setting following Traverse's (1988) suggestion that spores and pollens are present in virtually all depositional environments but that their relative abundance decreases towards the open ocean. The poor preservation of palynomorphs in Rocanville "B" may be attributed to slow deposition in a high pH environment as was postulated for some of the underlying sediments (i.e. lower Gravelbourg).

A peculiar sandstone body, at the base of Rocanville "B" in the Pondex Pat Parkman 5-22-10-1 well immediately south of the study area (Figure 11, in pocket), is characterized by a yellowish-orange to greyish-orange, moderately to poorly sorted, fine- to coarse-grained, clear quartz sandstone having high-angle planar cross-stratification. It has a sharply defined erosional contact with the underlying Rocanville "A" unit (Photo 5), and is interpreted to be a basal channel sandstone body of Rocanville "B". This apparent channel facies grades up into massive sandstones with low-angle planar cross-bedding and small-scale current ripple bedding, which resemble the regional sheet-like sandstone deposits at the base of Rocanville "B" in the Wapella-Moosomin area.

It appears that this channel sandstone infilled the incised underlying surface of Rocanville "A" and was overstepped by sheet-like sandstones which are likely equivalent to those found at the base of Rocanville "B" in the Wapella-Moosomin area (see Figure 11 in pocket). It is possible that similar channel-like sandstone bodies exist within the study area, but have not yet been penetrated by drilling. It is equally possible that they have been drilled, but were overlooked because they are not easily recognized on geophysical logs. Two localities were identified as possible areas where the basal portion of Rocanville "B" has infilled incised depressions in underlying strata. These localities are centered around the Tricent *et al.* Coothill 6-14-14-33 well and the CNW SRO Moosomin 11-8-13-32 well (see Figures 22 and 24). In both wells, the basal sandstones produce "blocky" or rectangular spontaneous potential (SP) curve signatures which are consistent with a channel sandstone interpretation.

The upper half of Rocanville "B" is characterized by variegated dolomitic mudstones, very fine- to fine-grained argillaceous and glauconitic/chamositic (?) sandstones (Photo 8), siltstones, and minor argillaceous dolostone. The variegated colouration of the rocks (Photo 10), ranges from dark reddish-brown through greyish-orange - colours indicative of oxidizing conditions (Berner, 1971). The variegated nature of the upper half of Rocanville "B" sediments and presence of dessication cracks (Photos 11 and 12) indicates that they were probably subaerially exposed at times and, in places, deposited in a supratidal environment. The dolomitic nature of these sediments further indicates a "restricted", and most likely hypersaline environment.

The presence of what appears to be glauconite and chamosite (?) (Photo 8) and glauconitic, pellet-like masses in some thin sections from the upper half of Rocanville "B" point to a marine shelf setting, at least for some of the sediments (Greensmith, 1978). On the other hand, the abundance of freshwater ostracodes such as *Darwinula* and *Limnocythere* in a few of the samples taken from Rocanville "B strongly suggests that at least some parts of this unit were deposited in, or proximal to, a freshwater-dominated environment.

In effect, the presence of both freshwater ostracode fauna and marine indicators like marine palynomorphs and local occurrences of glauconite and possibly chamosite, suggest that Rocanville "B" was deposited in a variety of depositional environments. This variation in depositional settings may be the result of periodic oscillations of the strandline on what was likely a shelf with a low gradient. On such a shelf, even a minor fluctuation in sea level would cause widespread shifts in the depositional environments.

Collectively, the lithological characteristics of the upper half of Rocanville "B" indicate a more restricted depositional environment, as compared with the lithologies of the lower half of Rocanville "B". Therefore, a restricted near-shore marine to supratidal depositional environment is envisaged for the upper half of Rocanville "B".

The contact between Rocanville "B" and Rocanville "C" is sharply defined but there is inconclusive evidence that removal of part of the underlying Rocanville "B" strata occurred (Photo 16). The contact likely represents a diastem only, an interpretation supported by the apparent development of a caliche with calcite infilled rootlet molds (?) at the top of Rocanville "B" in the CNW Wapella 14-2-15-1 well (Photo 13).

Rocanville "C" is characterized by interbedded sandstone, siltstone, mudstone, and oolitic bioclastic limestone (Photo 14), with interlaminated sandstone and siltstone being dominant. The presence of glauconitic pellet-like masses (Photo 9), dinoflagellates, marine ostracodes, pelecypods and, above all crinoids and corals (Photo 15) clearly demonstrates that Rocanville "C" was deposited in a dominantly open marine environment. This suggests that following the deposition of Rocanville "B", a wide-spread transgression occurred during Rocanville "C" time.

The combination of siliciclastic and carbonate lithologies in the Rocanville "C" sequence suggests a carbonate environment with sporadic influxes of siliciclastics. Current transport is the most likely mechanism for the mixing of the two lithologies. This mechanism is described by Maxwell and Swinchatt (1970) who have shown facies mixing where tidal flats and near-shore siliciclastic belts interfinger with deeper subtidal carbonate environments in the Great Barrier Reef of Australia. A similar mixing appears to occur in unit 2 of the Lower Shaunavon - the postulated equivalent of Rocanville "C" - which becomes increasingly interbedded with siliciclastic material as one approaches southeastern Saskatchewan.

Moosomin Member

An erosional disconformity exists between the Moosomin and Rocanville Member. The paleotopography created by erosion appears to have influenced the distribution of Moosomin "A" sediments in the study area. Comparison of the cross-sections in Figures 15 and 23 (in pocket) with the isopach map of the Rocanville in Figure 24 (in pocket) show that Moosomin "A1" infills the eroded surface of the underlying Rocanville Member. It can also be seen that Moosomin "A2" conformably overlies Moosomin "A1" in the paleo-valley and lowland areas, but oversteps the paleohighland areas where it disconformably overlies the eroded Rocanville Member.

The recognition of incised valley fills and their associated unconformities has been considered of crucial importance by Vail *et al.* (1977) when applying sequence stratigraphic concepts to dividing, correlating, and mapping sedimentary rocks. The Wapella-North Wapella paleo-valley and the Red Jacket-Rocanville paleo-valley are typical examples of such discontinuities.

Since the combined strata of Rocanville "B" and "C" has been equated to the Lower Shaunavon of southwestern Saskatchewan, the disconformity that defines the top of both the Lower Shaunavon and Rocanville "C" is undoubtedly coeval; i.e. the result of a relative drop in sea level affecting southern Saskatchewan. There appears to be little evidence of incision into the top of the Lower Shaunavon in southwestern Saskatchewan (Christopher, 1964); however, as much as 30 m of Rocanville strata were removed in the study area. The pronounced incision into the Rocanville Member suggests that, in addition to a drop in sea level, there may have been diastrophic uplift to the north and east which promoted fluvial downcutting.

Moosomin "A1" comprises an interbedded and interlaminated sequence of carbonaceous and pyritiferous sandstone, siltstone and mudstone. The olive-grey to medium grey colour, presence of disseminated and nodular pyrite and abundant well-preserved carbonaceous detritus in this subunit suggests a reducing depositional environment (Christopher, 1964).

Several lines of evidence also point towards a brackish-water or estuarine depositional setting for Moosomin "A1". These include: a low diversity but locally abundant ichnofossil suite composed solely of *Planolites* and *Chondrites* (Ekdale *et al.*, 1984), the common coexistence of pyrite and siderite (Wightman *et al.*, 1987), and abundant terrestrial palynomorphs indicates a strong continental influence on sedimentation. However, the presence of marine palynomorphs, *Leiosphaeridia* and (?) *Comasphaeridium* sp., in a Moosomin "A1" sample perhaps indicates there were brief incursions of salt water into a dominantly brackish-water environment.

On the basis of the overall paleogeographic evidence and the brackish-water character of the sediments in Moosomin "A1", the Wapella-North Wapella and Red Jacket-Rocanville paleo-valleys are interpreted to be estuaries. Pritchard (1967) defines an estuary as a semi-enclosed coastal body of water which has free connection with the open sea but in which freshwater from the land measurably dilutes sea water. The presence of sandstones showing bi-directional cross-bedding suggests opposing flow directions (Photo 18) and would support the interpretation of an estuarine deposit where tidal processes acted on the sediment (de Raaf and Boersma, 1971; and Klein, 1971). The lowland areas in Figure 24 (in pocket) are also interpreted to be part of this estuarine environment and may represent areas of coastal embayments. In summary, the paleogeographical, lithological and paleontological evidence collectively suggests that Moosomin "A1" was likely deposited under reducing conditions in coastal embayments and estuaries. The texturally immature and poorly sorted sandstones at the base of Moosomin "A1" as found in CNW Wapella 6-2-15-1 may represent a crevasse splay deposit.

Estuarine deposits rarely consist of infilling material laid down during a single still-stand of the sea. Instead, they tend to occur in an area where an estuary existed on and off for extended periods of time. Variations between marine and fluvial influences in these deposits result from minor fluctuations in sea level which cause an increase or decrease in the size of the estuary and its tidal prism (Clifton, 1982). Therefore, it is probable that within the apparent "estuarine" deposits of Moosomin "A1" there are likely to be sediments intermixed which are qualitatively more closely related to either fluvial or marine depositional environments.

The present-day coastline of eastern U.S.A. appears to be a modern-day analogue to the envisaged depositional setting for Moosomin "A1". A number of drowned river-mouth valleys (*i.e.* estuaries) exist along this coast due to the post-Pleistocene rise in sea level. Two of the largest and most famous examples are the Chesapeake Bay (Briggs, 1967) and Delaware Bay (Weil, 1977).

A possible ancient analogue to the Wapella-North Wapella and Red Jacket-Rocanville paleo-valleys may be valley fills described by Wood and Hopkins (1989) in the Lower Cretaceous "Glauconitic member" of the

Mannville Group in the Little Bow Field in southern Alberta. There, the paleo-valley is 2.0-2.5 km wide, the fill up to 30 m thick, and it has been traced over a length of 55 km. This example compares favourably with the Wapella-North Wapella paleo-valley in width and depth, but is approximately 2.5 times greater in length. Unfortunately, the lack of well penetration at either end of the Wapella-North Wapella paleo-valley trend precludes an accurate determination of the length of this feature. In the case of the Red Jacket-Rocanville paleo-valley, the geometry is deduced from even less well control, and no core is available from the proposed valley fill section (i.e. Moosomin "A1"). This valley trend appears to be approximately 3 times wider than the Wapella-North Wapella paleo-valley; has about the same 30 m depth, and appears to be continuous and mappable over a length of approximately 45 kilometres in the study area (see Figures 15, 23 and 24, in pocket).

Following the fluvial incision into Rocanville sediments a relative rise in sea level drowned the river valleys and low-lying areas. The interpreted sea level rise is supported by the gradational contact between Moosomin "A1" and Moosomin "A2", and by the overstepping or transgressive nature of Moosomin "A2" over the Rocanville paleohighlands throughout the study area (see Figures 15, 23 and 24, in pocket). The lithological and paleontological evidence from Moosomin "A2" also suggests a more marine environment than for Moosomin "A1".

Although Moosomin "A2" is lithologically similar to, and in gradational contact with Moosomin "A1", it differs from Moosomin "A1" by being less carbonaceous, more silty and finer grained, having rare interbeds of bioclastic limestone near its top, and by being glauconitic locally. These characteristics also point to a more marine depositional environment than is envisaged for Moosomin "A1".

The medium dark grey to olive-grey mudstones, and common occurrence of pyrite and organic detritus in Moosomin "A2" suggests deposition under reducing conditions. The scarcity of megafossils and trace fossils furthermore point to anoxic environments in both water and sediment.

Paleontological evidence from Moosomin "A2" strongly suggests that, relative to Moosomin "A1", it was deposited under conditions of greater marine influence. The recovery of a few species of dinoflagellates, acritarchs (Table 1) and Foraminifera from Moosomin "A2" support this interpretation. The mass occurrence of one foraminiferal species, genus *Ammodiscus*, in Moosomin "A2" suggests a marine depositional environment of lowered salinities, as may be found in a lagoonal setting sheltered behind a barrier-island complex and influenced by freshwater runoff (Braun, 1989, pers. comm.). The presence of the miliolid *Opthalmidium* in Moosomin "A2" is typical of a low-energy inshore depositional environment (Brooke and Braun, 1972).

Collectively, the lithological and paleontological evidence from Moosomin "A2" points to deposition largely in a low-energy, brackish-marine environment which was somewhat reducing. This may be a lagoonal setting behind a barrier-island complex which may have developed in front of the flooded estuarine valleys of Moosomin "A1".

It is envisaged that, with a rise in sea level, Moosomin "A1" and the paleohighlands of the Rocanville Member were transgressed and covered by sediments of Moosomin "A2". The transgressive shoreline depositional model is a difficult one to reconstruct because of the high variability in lithology and intricate stacking of facies. The model is characterized by subtidal and intertidal back-barrier facies and does not show a fining upwards nor coarsening upwards trend (Reinson, 1984). Moosomin "A2" does not appear to show an obvious fining upwards nor coarsening upwards sequence.

Unfortunately, the lack of well-control in the area immediately to the south and west of the study region precludes the possibility of proving or disproving the postulated existence of a barrier-island complex in a perceived "seaward" direction. Some sandstone bodies in Moosomin "A2" are well sorted and may be indicative of a barrier-beach or of a tidal delta deposit. The common occurrence of flaser and wavy bedding in the Moosomin "A2" sandstone strongly suggests a tidal influence (Reineck and Wunderlich, 1968) and subtidal facies (Weimer *et al.*, 1982).

The top of Moosomin "A" (i.e. Moosomin "A2") is sharply delineated but shows little evidence of erosion in the cores of the Wapella Field. It is commonly characterized by well-cemented, dolomitic sandstone which is generally overlain by a thin layer of variegated (i.e. oxidized) mudstone (Photo 23). Such a contact suggests a brief period of exposure and may even represent a diastem which marked the end of Moosomin "A" deposition. This apparent discontinuity has similar lithological characteristics and about the same stratigraphic position as the top of unit "U1" described by Christopher (1964) in southwestern Saskatchewan, implying that they may be coeval.

The break between Moosomin "A" and "B" can be readily recognized in core on the basis of the contrasting differences in the colour, composition, and texture of these units, but is difficult to recognize on a geophysical log. The dominantly greenish-grey colour and lack of carbonaceous detritus in the Moosomin "B" mudstones and siltstones contrasts with the light olive-grey to olive-grey mudstones and siltstones of Moosomin "A2".

Potter *et al.* (1980) suggested that the colour of a shale essentially reflects the amount of iron in the oxidized state (Fe^{3+}) and organic carbon that was active in the depositional environment. Moreover, the amount of organic matter preserved in the substrate is also an indication of oxidation levels. Since Moosomin "B" is generally free of carbonaceous detritus it is suggested that either plant material was not common to this unit or it was fully oxidized in this environment and, therefore, not preserved. In view of the relative abundance of marine palynomorphs, pelecypods, fish remains and ichnofossils in Moosomin "B" with respect to that observed in Moosomin "A2", better oxygenated bottom conditions are envisaged for Moosomin "B".

In a single interbed of olive-grey mudstone in Moosomin "B" well-preserved pelecypods were found. This is in contrast with very poor preservation in contiguous greenish-grey mudstone beds. Since both types of interbeds appear to have equally numerous pelecypod specimens and are devoid of carbonaceous material, their organic productivity seems to have been similar; thus the difference in colour is likely attributable to the difference in Eh potential of the bottom sediments. The excellent preservation of the pelecypod shells (*Thracia ? montanaensis*) and the olive-grey colour of this interbed suggests then a local reducing environment, whereas, the poor preservation of pelecypods in the typically greenish-grey siltstone of the contiguous beds suggests more oxidizing conditions.

A similar gross contrast in oxidation conditions is noted between Moosomin "A" and "B". There is an apparent shift from reducing conditions in Moosomin "A" to more oxidizing conditions in Moosomin "B". A likely mechanism for improved oxygenation would be agitation by wave or current action as in a shallow water depositional setting, or at least in a depositional environment with better circulation than is envisaged for Moosomin "A".

Lithologically, Moosomin "B" is characterized by an interbedded and interlaminated sequence of sandstone and greenish-grey mudstone with rare argillaceous limestone in the lower portions of the unit. The common presence of flaser, wavy and lenticular bedding (Photos 24 and 25), particularly in the upper 5 to 10 m of Moosomin "B" indicates a repeated alternation between current or wave action and slack water periods (Reineck and Wunderlich, 1968). This bedding type is commonly related to tidal rhythms and is considered an important criterion in the recognition of a tidally influenced deposit (Reinek and Wunderlich, 1968; Weimer *et al.*, 1982 and Reading, 1986).

Bioturbation is also a common feature in Moosomin "B", particularly in the upper 5 to 10 m of the unit resulting in a burrow-mottled texture (Photo 28). The low diversity but abundant trace fossils belonging to the *Glossifungites* (firm substrate) and *Skolithos* (shifting substrate) ichnofacies (Photos 36 and 37) indicates deposition in a biologically rigorous environment (Ekdale *et al.*, 1984). A freshwater to brackish-water ostracode assemblage, charophyte oogonia, *Botryococcus* algae, and possibly algal-laminated sediments (Photo 30) are evidence of freshwater to brackish-water setting. Syneresis cracks (Photo 29) in the upper 5 to 10 m of Moosomin "B" also suggest fluctuations in salinity, and mud cracks in the mudstones at the top of unit "B" (Photos 39 and 40) indicate subaerial exposure. Numerous truncation surfaces (Photo 31) and escape burrows (Photo 37) suggest extremes in current velocities resulting in erosion and rapid deposition.

In view of the above evidence, a tidal flat depositional environment is envisaged for Moosomin "B". Tidal flats are biologically stressful environments subject to extremes in currents, water depth, salinity, temperature, dessication, erosion and rapid deposition (Weimer *et al.*, 1982). Tidal flats are commonly divided into intertidal and subtidal environments. Although no single bedding type is restricted to deposition on a tidal flat, some bedding types are more abundant in one part than others (Reineck and Singh, 1980). For example, megaripple bedding is common in tidal channels (Reineck and Singh, 1967,), whereas flaser, wavy and lenticular bedding and finely interlayered sand/mud are common bedding types in intertidal deposits (Weimer *et al.*, 1982). Small-scale ripple bedding is typical of sandy intertidal flats (Reineck and Singh, 1980).

Areally, intertidal deposits make up the greatest portion of a tidal flat (Weimer *et al.*, 1982). The alternation in textures between sand and mud demonstrated by lenticular and flaser bedding in Moosomin "B", particularly in the upper 5 to 10 m, points to their origin in the intertidal zone. Repeated emergence is also characteristic of intertidal flat deposition (Klein, 1971). The presence of the *Glossifungites* ichnofacies, syneresis cracks and mud cracks in the upper 10 m of Moosomin "B" indicate repeated emergent conditions, and therefore intertidal zone deposition.

Subtidal areas and their genetically related tidal channels are important components of a tidal flat because of their high preservation potential. Most tidal flat deposition results from lateral accretion in association with progradation of the flat and point bar deposits of meandering tidal channels. The lateral accretion process results in greater preservation of features associated with channel fill and tidal point bars than of intertidal flat deposits (Weimer *et al.*, 1982).

Therefore, it is not surprising that tidal channels are found in the Wapella-Moosomin area (i.e. North Wapella and Moosomin localities, and the Red Jacket Field, see Figure 1). Although river and tidal channels share characteristics such as a fining-upwards sequence and mud pebble lag deposits at their base, there are other characteristics that enable us to distinguish between them. Recognition of tidal channels in Moosomin "B" is based upon the muddier nature of the sequence, the association of lenticular and flaser bedding (Blatt *et al.*, 1980), and the presence of mud drapes (Photo 32) (Nio and Yang, 1989). The fact that these channels appear to erode into, and are overlain by sediments showing considerable mixing of freshwater and marine faunas is more consistent with tidal channels than fluvial channels. The common presence of "coffee ground" organic detritus (Photo 34) in the channel deposits of Moosomin "B" indicates that peat was eroded in a landward position and was transported into the sedimentation cycle on a tidal flat (Reineck and Singh, 1980).

Moosomin "B" sediments were deposited under more oxygenated conditions than Moosomin "A2". Hence, the dominantly greenish-grey colour of the mudstones, siltstones and argillaceous sandstones in this unit. Moosomin "B" shows lithological, paleontological and sedimentological features which are commonly associated with tidal flats. Lenticular bedding, numerous truncation surfaces, intense bioturbation, syneresis cracks, the presence of charophyte oogonia and abundant freshwater to brackish-water ostracodes point to an overall shallowing and probable deposition on a tidal flat in the upper 5 to 10 m of Moosomin "B". An overall fining-upwards sequence into bioturbated sands and muds, ending in an exposed and dessicated surface, suggests progradation of intertidal flat deposits over subtidal channel fill and tidal point bar deposits (Reineck, 1967; Klein, 1971 and Evans, 1975).

A possible modern analogue to Moosomin "B" deposition are the tidal flat deposits of the North Sea coast of Europe (Weimer *et al.*, 1982).

As discussed earlier, Moosomin "B" was equated with unit "U2" and likely part of unit "U3" of the Upper Shaunavon described by Christopher (1964) in southwestern Saskatchewan; where channel deposits of apparent tidal origin are also common.

Burrows Member

Sandy and argillaceous material at the base of Burrows "A" commonly infills mud cracks in mudstones at the top of Moosomin "B" (Photos 39, 40 and 41). The lower 30 to 40 cm of Burrows "A" has minor interlaminations of sandy, micaceous siltstone, and very fine-grained micaceous sandstone but grades vertically over this distance into the medium grey to dark grey, weakly calcareous claystone and mudstone which characterizes this unit.

The presence of abundant *Ammodiscus* sp. and *Opthalmidium* sp. - two species of Foraminifer - throughout Burrows "A", suggests deposition of these beds in a relatively low energy, brackish-water to marine depositional environment (Brooke and Braun, 1972). *Gonyaulacacean* dinoflagellates are also scattered throughout unit "A", indicating deposition in an open-marine environment (Williams, 1978) and implying that a minor marine transgression occurred during Burrows "A" time. The remarkably uniform thickness (i.e. 2.5 to 3.2 m) and widespread distribution of this unit (Figures 4b, 11 and 12, in pocket) also supports such an interpretation.

Burrows "A" grades over a vertical distance of less than 50 cm into lenticularly bedded and bioturbated sandstones, siltstones and mudstones of the overlying Burrows "B". Burrows "B" exhibits all of the lithological, paleontological and ichnological features that the upper 5 to 10 m of Moosomin "B" shows. It is lenticularly bedded with greenish-grey mudstones and siltstones, and light greenish-grey to very light grey, very fine- to fine-grained, moderately to well sorted quartzose sandstones (same as Photo 24). Bioturbation is represented by *Diplocraterion* and *Planolites* burrows in this unit (same as photos 37 and 38) and is typically moderate to intense, commonly resulting in the same "burrow-mottled" texture that is typical of the upper part of Moosomin "B" (Photo 26). Like Moosomin "B", Burrows "B" yielded abundant brackish-water to freshwater ostracodes such as, *Metacypris* cf. *tenuimarginata* and *Darwinula oblonga*, as well as numerous occurrences of charophyte oogonia. The latter two fossils are freshwater indicators.

Apparently, Burrows "B" was deposited in a similar, if not identical environment to that of the upper 5 to 10 m of Moosomin "B", i.e. the intertidal portion of a tidal flat. This implies that immediately following the minor marine transgression of Burrows "A", there was a minor regression and a return to deposition on a tidal flat similar to that of Moosomin "B" time.

The Rierdon Formation

The top of Burrows "B" by definition is the top of the Red Jacket Formation. A thin (less than 1.5 m), *Gryphaea*-bearing sandstone subunit is commonly found in core at the base of the calcareous mudstones of the overlying Rierdon Shale in the study area (Photo 4). In core, the contact at the base of this sandstone is found to be sharp and erosive, and is interpreted to be a lag deposit in disconformable contact with the underlying greenish-grey mudstones and very light grey sandstones of Burrows "B". Nevertheless, this *Gryphaea*-bearing sandstone is included on geophysical logs in the top of Burrows "B" for practical reasons as discussed earlier.

The moderate sorting of the coarse clastics and well-worn nature of the pelecypod shell fragments supports the interpretation that this sandstone subunit is a lag deposit, whereas the presence of glauconite in the sandstone suggests a marine environment. Paleontological and palynological evidence clearly suggests normal marine conditions for the overlying calcareous mudstones of the Rierdon Shale. The gradational contact between the thin *Gryphaea*-bearing sandstone and the overlying calcareous mudstones of the Rierdon Shale implies that it is the sandstone that marks the beginning of the transgression in this area (see Appendix C.6 for core description).

In summary, it appears that immediately following the discontinuity at the end of Burrows "B" time, the sea again transgressed over the entire study area. In some localities, the basal transgressive unit was marked by a thin (less than 1.5 m thick), *Gryphaea*-bearing sandstone lag deposit. Deposition in a normal marine environment appears to have persisted throughout Rierdon Shale time in the Wapella-Moosomin area.

The Rierdon Shale is the youngest stratigraphic unit of Jurassic age recognized in the region of study; however, much of it has been removed by erosion below the sub-Cretaceous unconformity.

Paleotectonic Controls on Sedimentation

Kent (1987) described a number of structural elements which appear to indicate long-term weaknesses that may have had an effect on subsidence in the Williston Basin. The western portion of the basin is underlain by Archean basement of the northwestern Churchill and Wyoming structural provinces which, in turn, are interpreted to be components of an early Proterozoic paleocontinent. The eastern margin of this paleocontinent appears to be approximately coincident with the North American central plains (NACP) electrical conductivity zone (Figure 2). The eastern portion of the basin appears to be underlain by Archean basement of the Superior structural province. The Birdtail-Waskada Axis in Manitoba is a north-south-trending geophysical feature consisting of numerous structural and isopach anomalies in Devonian and younger strata, and is considered to represent the approximate western margin of the Superior structural province (McCabe, 1967 and 1971). Kent (1987) showed the north-south-trending Birdtail-Waskada Axis to extend down into eastern South Dakota, approximately parallel to the NACP (Figure 2).

Lewry (1984) postulated the existence of a "suspect terrane" collage of early Proterozoic magmatic arcs, volcanogenic metasedimentary rocks, ultramafic rocks, and possible microcontinental remnants between the Churchill and Wyoming paleocontinent and the Superior craton. The observation of Hajnal and Fowler (1982) that the crust beneath the eastern portion of the Williston Basin is anomalously thick supports Lewry's idea and would be expected in a zone of collisional suturing of two continental plates (Dickinson, 1976). Kent (1987) suggested that this mobile belt passes through the centre of the Williston Basin and thus may have been the locus of intermittent reactivation of the basement during Phanerozoic deposition.

The Birdtail-Waskada Axis is important to the present study as it passes directly through the Wapella-Moosomin area. The Nelson River gravity trend, which also passes through the area, is located immediately west of, and parallel to, the Birdtail-Waskada Axis (Figure 2) (see also Macdonald and Broughton, 1980). This gravity trend is believed to mark the boundary between the Churchill and Superior provinces.

It is significant that a number of Paleozoic stratigraphic units become thinner from west to east as they approach this north-south axis near the Saskatchewan-Manitoba border. Christopher (1961) for instance, showed a pronounced thinning of the Upper Devonian Torquay Formation in the area immediately west of and parallel to the Saskatchewan-Manitoba border. He also showed the eastern, erosional edge of the lowermost Mississippian Lower Bakken Shale Member trending approximately north-south along the same border.

McCabe (1967) reported anomalous thickening of Paleozoic strata in the Manitoba portion of the Williston Basin (i.e. southwestern Manitoba), particularly in Ordovician and Mississippian sections. He also noted that the same area experienced a greater degree of pre-Jurassic uplift and erosion, resulting in thick basinal facies of these strata being exposed at the erosional surface. He concluded that these observations "...may be the result of a greater response of the Superior block to the tectonic forces giving rise to both basin subsidence and basin uplift." He also pointed out that the Birdtail-Waskada Axis marks the approximate eastern edge of the Prairie Evaporite salt basin (see Figure 2) and the approximate western edge of the Winnipegosis fringing reef trend. These coincidences strongly suggested to him that these features may be related to the projected Churchill-Superior boundary in the Precambrian basement.

Christopher (1984) described a south-trending ridge of subcropping Mississippian strata along longitude 102°W which separates the Saskatchewan portion of the Williston Basin (lower Watrous sub-basin) from the lower Amaranth sub-basin in Manitoba (Figure 3). He concluded that uplift of the intervening area took place sometime during post-Mississippian to pre-Triassic time. The uplifted area appears to be coincident with the Birdtail-Waskada Axis and the Nelson River gravity trend, and includes the Wapella-Moosomin area (Figure 2).

The near coincidence of zero limits of the lower and upper members of the Watrous Formation, and units A and B of the lower member of the Gravelbourg within the Wapella-Moosomin area, suggests that there must have been some paleotectonic control on their present distribution. These units show a progressive overstepping of younger over older units in a northeasterly direction as they onlap a south-trending ridge of the Mississippian subcrop (Figure 7 in pocket). The notable exception to this progression is unit A of the lower Gravelbourg, which, can be explained by erosion of the top of the unit.

It is possible that truncation of some Middle Jurassic units in the study area may have been caused by periods of uplift, as well as contemporaneous regression (for example, truncation of unit A of the lower Gravelbourg (Figures 4b, 11 and 12 in pocket) and the Rocanville "A" unit (Figure 11 in pocket)). Similarly the incision of up to 30 m below the unconformity at the top of the Rocanville Member in the Wapella-Moosomin region (see Figures 15, 23 and 24, in pocket) might: a) reflect uplift of the study area or of the hinterland to the northeast, b) reflect downcutting by rivers in response to lowered base levels, coincident with a relative drop in sea level (i.e. regressions), or c) a combination of regression and uplift.

Thinning of Jurassic strata in the area along the Saskatchewan-Manitoba border was also reported by Klingspor (1958). He suggested that a pre-Jurassic high, which shows up in Mississippian and older Paleozoic beds in this area, influenced the distribution of Jurassic sedimentation and accentuated erosion after the Nevadan uplift in the Late Jurassic. He also pointed out that the erosional edge of the Jurassic forms an indentation southward into the basin (Figure 4a in pocket).

It is noteworthy that Halabura's (1983) isopach maps of the Upper Devonian Birdbear Formation show a thinning of the unit in an area immediately north of the Wapella-Moosomin area. He named this area the Punnichy Platform which seems to be coincident with the Punnichy Arch postulated and described by Christopher (1980 and 1984). Christopher (1980) believed it to have been active during Albian time and suggested that a similar feature detectable on the Silurian isopach map of Paterson (1975) may have been active at that time as well.

The stratigraphic evidence suggests that the region along the Saskatchewan-Manitoba border, has undergone periodic uplift or arching, at least in part related to reactivation and movement along the ancient suture zone separating the Superior and Churchill Provinces. It is herein proposed that the north-south-trending arch approximately coincident with the Birdtail-Waskada Axis, be named the Birdtail-Waskada Arch (see Figures 2 and 3). This arch is possibly a south-trending extension of, or a block related to, the Punnichy Arch.

The Birdtail-Waskada Arch was uplifted sometime during Late Devonian to Early Mississippian (Christopher, 1961, Torquay Formation and Lower Bakken), post-Mississippian to pre-Triassic (Christopher, 1984, lower Watrous-Amaranth), and Middle Jurassic time (this paper, lower Gravelbourg and Rocanville).

It is likely that structural movement related to paleotectonic features like the Nelson River gravity trend and the Birdtail Waskada Axis played a role in the creation of the NE-SW trending salt solution features described earlier in southeastern Saskatchewan, and in particular, in the Wapella-Moosomin area.

Economic Considerations

The Wapella-Moosomin area includes all known economic occurrences of hydrocarbons in Middle Jurassic reservoirs in southeastern Saskatchewan. Most hydrocarbon production in this area comes from the Wapella and Red Jacket pools and a number of scattered wells nearby. Other production comes from the area in and around the North Wapella and Moosomin localities (Figure 1). The oil produced is a medium gravity ranging from 906 to 960 kg/m^3 (16° to 25° API) from reservoirs at depths between 650 to 780 m. The shallow depth of burial has resulted in minimal compaction of reservoir sandstones such that porosity is generally greater than 25 percent.

The Wapella pool has produced oil since 1952 from a basal Mannville (Lower Cretaceous) sandstone unit informally known as the Wapella Sandstone (i.e. Dina equivalent?) and from a number of discontinuous sandstone bodies in the Middle Jurassic Moosomin and Rocanville members of the Red Jacket Formation. Hydrocarbon production in these reservoirs has been commingled since 1960, with initial oil in place estimated to be some $14.5 \times 10^6 m^3$. Wells which produce only from Jurassic reservoirs in and around the Wapella and Red Jacket pools, contain approximately $4.6 \times 10^6 m^3$.

The Red Jacket pool began oil production in 1984. The majority of the oil comes from sandstones in Moosomin "B" of the Moosomin Member which are estimated to have reserves of $2.6 \times 10^6 m^3$. A single well in the Red Jacket pool (i.e. Tricent *et al.* Red Jacket 11-4-14-32) produces from a sandstone in the lower Gravelbourg with estimated reserves of $0.22 \times 10^6 m^3$.

Several geological conditions appear to have been responsible for oil entrapment in the Jurassic sediments of the Wapella-Moosomin area. It is believed that the oils in place have leaked out of the underlying Mississippian subcrop (van Delinder, 1984 and Brooks *et al.*, 1987). At present all known occurrences of Middle Jurassic oil in the southeast occur either beyond the zero limit of the lower Watrous red beds or where the lower Watrous is thin (Figure 14, in pocket). This suggests that the lower Watrous may have acted as a seal during the time of oil migration, but this is not necessarily the case. Very few wells have been drilled between the Wapella and Red Jacket pools and the Mississippian oil fields 30 km to the south. The oil potential of the Jurassic in this area is relatively unknown.

All of the known Middle Jurassic oil production in the Wapella-Moosomin area is underlain by upper Watrous rocks. In most of the producing wells upper Watrous strata rests directly upon the Mississippian subcrop (Figure 13, in pocket). The interbedded dolomites and anhydrites of the upper Watrous show considerable evidence that they were not effective seals to upward oil migration, as they are commonly brecciated and display vertical fractures which are sealed by gypsum. Furthermore, a core taken from Central Del Rio Red Jacket 6-19-13-32 shows oil staining in dolostone and bitumen coating along some fractures. As discussed previously the brecciation was attributed to exposure and weathering processes shortly after deposition. The vertical fractures resemble those found in the underlying carbonates of the Souris Valley Beds. It is possible that at least some fracturing occurred in response to the Laramide orogenic event in Late Jurassic to Early Cretaceous time. Fracturing of Mississippian and upper Watrous rocks promoted migration of oil into Jurassic and Cretaceous strata in the Wapella-Moosomin area. A number of the localities showing structural highs are oil productive (Figure 9 and 10, in pocket). This suggests that fracturing and 'doming' related to the far-reaching affects of the Laramide orogeny probably played a significant role in oil emplacement.

It is plausible that fracture systems, similar to those observed in the Mississippian and upper Watrous in the Wapella-Moosomin area, exist in the area to the south. If so, all potential Jurassic and Cretaceous reservoir rocks in that area could contain hydrocarbons.

A few miscellaneous wells in township 7, range 1 west of 2 in southeast Saskatchewan produce from sandstones near the base of the lower Watrous. Significant volumes of oil are also produced from silty sandstones of the lower Amaranth (i.e. lower Watrous equivalent) in the Waskada and Pierson fields of southwestern Manitoba. This shows that areas outside the Wapella-Moosomin area possess hydrocarbon reservoirs of leaked Mississippian oil.

The oldest Middle Jurassic unit in southeastern Saskatchewan to show hydrocarbon accumulation is unit B of the lower Gravelbourg. Generally, the sandy peloidal bioclastic limestones and quartzose sandstones of this unit are well-cemented with calcite. Nevertheless, oil is presently being produced from a weakly calcite-cemented lower Gravelbourg sandstone in the Tricent *et al.* Red Jacket 11-4-14-32 well in the Wapella-Moosomin area. The overlying Modiolus (?) -bearing mudstones of unit B of the lower Gravelbourg provide the necessary seal for oil entrapment. Production from the lower Gravelbourg Tricent *et al.* Moosomin 4-28-14-31 well was also attempted but was subsequently abandoned due to the poor quality of the reservoir. Locating areas in which the sandstones and sandy limestones of unit B are weakly cemented is critical to the discovery of economic reserves of hydrocarbons in stratigraphic traps in the lower Gravelbourg. Unfortunately, the available geological data does not appear to permit the prediction of such areas, but recent advances in seismology may provide the explorationist with the means for their discovery.

The next oldest Middle Jurassic reservoir type in the study area is in Rocanville "B". In this unit, a sequence of what appear to be predominantly near-shore marine shelf and relict beach sandstones form stratigraphic traps in the Wapella pool and in the area centred on the Tricent *et al.* Coothill 6-14-14-33 well. Cross sections suggest that these sandstone bodies have a sheet-like distribution and are stacked in some places (Figures 11, 12, 15, and 23, in pocket). In the case of the area around Tricent et al. Coothill 6-14-14-33 some of the lowermost portion of Rocanville "B" may be a channel sandstone infill as discussed previously.

Calcite- and dolomite-cemented sandstone intervals at or near the top of these sandstones commonly provide an effective seal for oil entrapment. Alternatively, enveloping siltstones and dolomitic mudstones act as seals in these reservoirs. Although these traps appear to be largely stratigraphic in nature there also appears to be a structural component to some of them. Locally, anomalous thickening of the Rocanville Member in both the Wapella pool and in the area centred on Tricent *et al.* Coothill 6-14-14-33 strongly suggest the presence of sinkholes in these localities (Figures 24 and 25, in pocket). The multi-stage dissolution of the underlying Devonian Prairie Evaporite and the resulting collapse of overlying strata could have played a major role in the creation of these anomalies and their structural configuration. Both the Wapella pool and the area around Tricent *et al.* Coothill 6-14-14-33 show evidence of collapse structures and both are hydrocarbon producers. Thus besides providing structures conducive to oil entrapment, collapse structures could also be responsible for migration of oil into the traps. Targeting salt dissolution/collapse structures may therefore help to find hydrocarbon reservoirs in Middle Jurassic and Lower Cretaceous strata.

Exploration should follow the apparent north-northeast to south-southwest trend of the suspected solution/collapse structures (Figure 25, in pocket). Not all areas of solution/collapse are going to be traps despite having anomalously thick sandstone sequences as for example in the Chevron Clayridge 8-10-17-1 well. Hydrocarbons could exist, however, in these sandstones in an updip direction to the northeast.

Seismic exploration in combination with an understanding of the sedimentology of Rocanville "B" would be a logical approach to locating sandstone reservoirs in this unit. These sandstones probably form stratigraphic traps in other places than the Wapella pool and the area centred around Tricent *et al.* Coothill 6-14-14-33. Unfortunately, mapping the distribution of the sheet-like marine shelf sandstone facies at the base of Rocanville "B" was beyond the scope of the present study.

The next youngest reservoir in the Wapella-Moosomin area is a stratigraphic trap formed within subunit Moosomin "A1", which is found in a few wells in the Wapella pool (e.g. CNW Wapella 6-2-15-1). It is interpreted to be a sequence of valley fill material in the Wapella-North Wapella paleo-valley (Figure 24, in pocket). Sandstones at the base of Moosomin "A1" tend to be texturally immature and are poorly sorted. They were likely deposited in a fluvial or estuarine depositional environment, in small channels or perhaps as crevasse splays. Exploration for reservoirs of this type in Moosomin "A1" would likely meet with the greatest success within, or on trend with, the Wapella-North Wapella and Red Jacket-Rocanville paleo-valleys (Figure 24, in pocket) - the area in which these facies are most likely to occur.

In the Wapella pool, oil is also found in the overlying Moosomin "A2" subunit which is interpreted to have been deposited in a reducing low-energy, brackish-marine environment, possibly as part of a barrier-island complex. Sandstones in this unit are commonly discontinuous and vertically stacked. Exploration for stratigraphic traps of this type is difficult and requires numerous closely spaced wells to determine their complex distribution.

Siltstone and mudstone interbeds often envelop discrete sandstone lenses in this unit creating the necessary seals for oil traps. In some wells, widespread dolomite- and calcite-cementation of sandstones at or near the top of Moosomin "A" effectively traps the oil (e.g. Saskoil Wapella 7-35-14-1).

Stratigraphic traps within Moosomin "B" represent the uppermost stratigraphic level of Jurassic hydrocarbon production in southeastern Saskatchewan. Most of the oil trapped in this unit occurs in tidal channel sandstones within the subtidal portion of the tidal flats, as for example in the Red Jacket pool, in the North Wapella and Moosomin localities, and in the areas centred on Coho *et al.* Welwyn 1-16-15-31 and Coho *et al.* Burrows 13-1-16-1. The Red Jacket pool, the Moosomin locality and the area around Coho *et al.* Welwyn 1-16-15-31 have a north-northeast to south-southwest trend (Figure 1). These locations are within, or close to, the northeast to southwest trend of thickness anomalies (Figure 25, in pocket), which are coincident with, or parallel to, the Red Jacket-Rocanville paleo-valley (Figure 24, in pocket). Again, areas of hydrocarbon accumulation appear to be closely associated with areas of salt dissolution-collapse structures.

Sandstone bodies of similar character and stratigraphic level to those found in Moosomin "B" are also oil reservoirs in an area centred on the Troy St. Lazare 1-21-16-29 well in southwestern Manitoba. This demonstrates the potential for hydrocarbon entrapment in Middle Jurassic sediments outside the area delimited in this study.

In summary, abundant Jurassic sandstone bodies of excellent reservoir quality at shallow depth in an oil-prone area suggests a great potential for further discoveries in southeastern Saskatchewan and southwestern Manitoba. The well control is generally poor and the area is virtually unexplored. Given the discontinuous nature of the sandstones the reservoirs are not likely to be of large areal extent, but their abundance regionally and stratigraphically holds great promise for significant volumes of oil to have been trapped.

Summary and Conclusions

Evaluation of sedimentologic, paleontologic, and geophysical well log data of the Wapella-Moosomin area has established the stratigraphic relationships between the type area for the Jurassic strata in southwestern Saskatchewan and equivalent rocks in the southeast. Four formations are recognized and mapped in the Wapella-Moosomin area of southeastern Saskatchewan. They are, in ascending order, the Watrous, Gravelbourg, Red Jacket and Rierdon formations.

An arbitrary lithofacies cut-off separates the Red Jacket Formation in the southeast from the upper member of the Gravelbourg and the Shaunavon Formation of southwestern Saskatchewan. A number of discontinuities are recognized in the Red Jacket Formation and are used to divide it into members and units, which include (from oldest to youngest): the Rocanville, Moosomin, and the Burrows members. These, in turn, are separated into Rocanville "A", "B" and "C"; Moosomin "A" and "B"; and Burrows "A" and "B". In places, Moosomin "A" is further divided into the subunits, Moosomin "A1" and "A2". The discontinuities between the above units record periods of regression which result in breaks in sedimentation ranging from diastems to obvious unconformities (Figure 16).

The Triassic-Jurassic (?) red beds of the lower Watrous represent the earliest post-Mississippian deposits in the Wapella-Moosomin area. Sedimentological features observed along with palynological evidence from the literature suggests that the lower Watrous was deposited in a restricted marine environment but with considerable terrestrial influence whereby the sediments were repeatedly exposed and reworked. It is unclear if the contact between the lower and upper Watrous is conformable or unconformable due to a lack of paleontological evidence. Lithological evidence from the study area and palynological evidence from the literature suggest, however, a restricted marine depositional setting for the upper Watrous.

The lower Gravelbourg, as defined in this report, is divided into a lower unit A and an upper unit B, separated by a disconformity which is recognizable in both southwestern and southeastern Saskatchewan. Unit B does not appear to be present in the type section for the Gravelbourg Formation but is recognized immediately to the east of it from which point it can be traced as far east as the Wapella-Moosomin area (Figure 4b).

Unit A of the lower Gravelbourg shows an intertonguing relationship with the upper Watrous in the southeast. Lithological and paleontological evidence from unit A suggests that it was also deposited in a marine environment with some evidence of restriction. The increase of minor amounts of fine-grained quartzose sandstone and scattered quartz grains in this unit towards the southeast suggests that the source for the quartz was from one or more localities to the east of the study area.

Lithological and paleontological evidence suggests that a hiatus occurred after unit A was deposited. After this break, dominantly marine deposition resumed and prevailed through unit B time.

An abrupt lithological and palynological change between unit B of the lower Gravelbourg and Rocanville "A" of the Rocanville Member suggests progradation of near-shore depositional settings when Rocanville "A" was deposited. It appears to have been laid down under reducing conditions in a near-shore marine to continental depositional setting bordering an inland sea, perhaps with extensive swamps along an inland coastal plain.

An apparent erosional disconformity at the base of Rocanville "B" has removed Rocanville "A" in all but a few locations in the study area. This was followed by the deposition of sheet-like bodies of sandstone at the base of Rocanville "B" which blanket most of the Wapella-Moosomin area. Lithological and sedimentological evidence suggests that the basal sandstones may be near-shore marine shelf sandstones and, in places, relict beach deposits. In places, the lowermost portion of some of these sandstone bodies are poorly sorted, show high angle planar cross-stratification, have a sharp and erosive base, and infill an underlying eroded topography. These sandstones are interpreted to be channel sandstones.

Sedimentological and paleontological evidence suggests that the upper half of Rocanville "B" was deposited in a restricted near-shore marine to supratidal depositional setting and that it was periodically exposed. The relative scarcity of sandstone in the upper half of this unit suggests a waning of clastic influx during this time.

A discontinuity signals the end of Rocanville "B" sedimentation, followed by a minor transgression during which Rocanville "C" was deposited in a dominantly open marine environment. This sedimentation phase was followed by a significant hiatus during which much of Rocanville "C" was removed and, in places, strata of the entire Rocanville Member were incised to approximately 30 m maximum depth.

Sedimentological and paleontological evidence, along with isopach mapping of the Rocanville Member, indicate that estuarine sediments belonging to Moosomin "A1" infilled paleo-valleys and other low-lying areas of the incised upper surface of the Rocanville Member. A continuous rise in sea level appears to have flooded the study area leading to deposition of Moosomin "A2". Paleontological and sedimentological evidence suggests deposition in a reducing, low-energy and brackish-marine environment - perhaps in a lagoonal setting behind a barrier-island complex.

A discontinuity once again denotes the end of Moosomin "A" deposition. Sedimentological and paleontological evidence from Moosomin "B" suggest deposition in subtidal and intertidal portions of a tidal flat. An overall progradation of intertidal over subtidal facies is envisaged for Moosomin "B".

A discontinuity indicated by dessication cracks marks the end of Moosomin "B" deposition in the study area. This was followed by a minor transgression and deposition of Burrows "A" in a low-energy, marine depositional setting. Burrows "A" has a gradational contact with Burrows "B". Based on sedimentological and paleontological evidence unit B is interpreted as a tidal flat deposit that is similar in kind to the upper portion of Moosomin "B" suggesting a minor regression at that time.

All evidence from the Rierdon Shale points to deposition in a fully open-marine environment. A thin (less than 1.5 m thick) *Gryphaea*-bearing sandstone lag deposit marks the initial transgression of the Rierdon Shale, but for practical purposes it is included in the top of Burrows "B" (i.e. top of Red Jacket Formation).

An apparent north-south trending arch, named the Birdtail-Waskada arch appears to have been active in Late Devonian-Early Mississippian, post-Mississippian-pre-Triassic and possibly Middle Jurassic time in the study area causing repeated relative lowering and raising of sea level, and some of the oscillations in the strandline. Structural movements related to this arch likely played a significant role in salt dissolution and related syndepositional thickening of Red Jacket strata in the Wapella-Moosomin area.

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Appendix A: Well Data

Table A.1 - Tops of Stratigraphic Units Picked.

In this table, on the following pages, blank spaces below the lowest depth given for a particular well indicates that the well terminates short of those horizons.

The letter "E" indicates that the formation was erodert. When a value for a given stratigraphic pick is followed by the letter "E" (e.g. 681.8E) it indicates that this stratigraphic unit has been partially eroded below the major unconformity at the base of the Cretaceous.

WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	PIERSON FORMATION	RED JACKET FORMATION						LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
					BURROWS MEMBER BURROWS "B"	BURROWS MEMBER BURROWS "A"	MOOSOMIN MEMBER	ROCANVILLE MEMBER ROCANVILLE "C"	ROCANVILLE MEMBER ROCANVILLE "B"	ROCANVILLE MEMBER ROCANVILLE "A"						
RANGER ET AL FLEMING 12-7-12-30	01-12-07-12-30-1	579.4	585.1	643.1	680.3	688.9	691.4	E	729.1	E	759.0	E	786.6	811.1	815.0	
SASKOIL ET AL FLEMING 8-13-12-30	01-08-13-12-30-1	542.5	523.3	577.8	610.8	618.3	621.0	E	659.3	E	682.0	E	695.1	E	726.3	
ASSINIBOINE ET AL FLEMING 9-13-12-30	01-09-13-12-30-1	539.1	519.0	570.4	605.7	613.0	615.4	E	655.0	E	677.3	E	686.1	E	725.0	
ASSINIBOINE ETAL FLEMING 16-13-12-30	01-16-13-12-30-1	542.0	524.7	575.1	616.0	621.5	624.1	E	664.0	E	686.2	E	692.8	E	728.7	
RIDEAU FLEMING 14-15-12-30	01-14-15-12-30-1	559.2	550.0	602.8	632.0	641.6	644.2	E	672.0	E	705.0	E	717.2	E	755.0	
SASKOIL PIPESTONE FLMNG 10-16-12-30	11-10-16-12-30-1	566.2	556.5	612.5	641.0	650.3	652.9	E	682.0	E	709.0	E	724.0	E	765.0	
SASKOIL PIPESTONE FLEMING 6-19-12-30	01-06-19-12-30-1	575.9	579.3	634.8	661.0	670.3	672.9	E	707.3	E	740.0	E	748.0	791.0	794.0	781.0-798.5
SASKOIL ET AL FLEMING 10-24-12-30	01-10-24-12-30-1	543.2	523.5	575.0	615.0	621.0	623.6	E	659.0	E	681.8	E	691.2	E	720.7	
TRICENT ET AL FLEMING 8-25-12-30	11-08-25-12-30-1	544.8	518.1	570.1	600.4	608.1	610.6	E	667.7	E	673.8	E	683.0	E	710.9	
SASKOIL PIPESTONE FLMNG 3-27-12-30	01-03-27-12-30-1	557.9	543.1	596.8	626.3	635.8	638.2	E	686.3	E	701.8	E	715.0	E	750.0	
TEXACO FLEMING R/A 13-32-12-30	02-13-32-12-30-1	575.6	567.8	611.1	648.9	656.5	659.0									
TENN FLEMING 4-11-13-30	01-04-11-13-30-1	540.1	513.6	563.6	585.8	594.7	597.1	E	624.0	E	638.1	E	670.9	E	682.2	
GULF FLEMING 7-11-13-30	21-07-11-13-30-1	535.9	511.9	562.4	585.2	593.5	596.0	E	629.1	E	651.7	E	666.0	E	691.0	
CONO ET AL FLEMING 6-18-13-30	41-06-18-13-30-1	561.7	543.0	593.0	615.5	623.5	626.0	E	666.0	E	689.1	E	700.2	E	731.3	664.0-681.8
CONO ET AL FLEMING W 11-22-13-30	01-11-22-13-30-1	536.3	502.0	560.0	575.0	581.5	586.0	E	619.0	E	646.0	E	660.0	E	683.0	
CONO ET AL FLEMING 6-23-13-30	31-06-23-13-30-1	528.3	495.0	539.0	567.0	572.7	575.0	E	608.5	E	634.4	E	650.0	E	660.6	
CONO ET AL KIDD CREEK 10-25-13-30	41-10-25-13-30-1	519.7	478.4	526.9	549.0	554.0	556.0	E	590.0	E	625.8	E	632.5	E	642.0	561.0-578.5
SCEPTRE MOOSOMIN 14-3-14-30	31-14-03-14-30-1	521.0	475.0	531.5	542.7	546.5	549.0	E	591.0	E	610.6	E	625.0	E	637.0	
CAL-STAN T.W. BOUNDARY 5-14-14-30	01-05-14-14-30-1	518.2	467.6	525.2	536.4	540.4	542.5	E	577.3	E	598.6	E	607.8	E	618.7	542.5-543.7
SCEPTRE MOOSOMIN 6-18-14-30	11-06-18-14-30-1	535.9	491.1	545.0	558.0	562.8	565.5	E	609.0	E	626.0	E	639.0	E	655.0	
TRICENT ET AL MOOSOMIN 12-29-14-30	31-12-29-14-30-1	525.1	470.0	522.0	536.8	539.8	542.0	E	579.0	E	600.7	E	615.0	E	626.3	
CONO ET AL MOOSOMIN 3-31-14-30	41-03-31-14-30-1	527.2	477.8	528.9	541.4	546.3	548.9	E	605.0	E	620.9	E	625.0	E	628.0	
RIDDLE TIDEWATER CAILMONT CR 2-6	01-02-06-15-30-1	521.8	472.4	526.6	533.4	539.2	541.6	E	589.2	E	606.1	E	611.7	E	616.9	
CO-OP DOME ET AL WELWYN 13-9-15-30	01-13-09-15-30-1	522.1	459.3	501.4	518.2	520.6	522.7	E	563.9	E	580.0	E	591.3	E	595.6	
RIO-PAL CAL-STAN WELWYN 16-17-15-30	01-16-17-15-30-1	521.8	453.8	499.3	510.8	513.3	515.4	E	545.6	E	573.0	E	E	E	586.7	
HOME ET AL WELWYN 5-23-15-30	21-05-23-15-30-1	513.8	442.8	E	E	E	503.7E	E	529.0	E	556.5	E	E	E	569.3	
TENNECO JORDAN WELWYN 2-29-15-30	01-02-29-15-30-1	518.8	449.3	490.7	504.7	507.2	509.6	E	538.3	E	562.7	E	E	E	577.0	
CONO ET AL WELWYN 5-31-15-30-1	31-05-31-15-30-1	523.2	449.1	490.5	495.8	498.3	500.8	E	566.0	E	E	E	E	E	575.8	
WHITEHALL ET AL ELIM 13-6-16-30	01-13-06-16-30-1	519.7	446.8	E	493.8E	496.8	499.3	E	565.8	E	E	E	E	E	567.5	
ROCAN - ROCANVILLE 15-6-16-30	01-15-06-16-30-1	519.7	446.5	496.7	496.8	500.2	502.9	E	E	E	556.6	E	E	E	561.8	
ROCAN ROCANVILLE 5-7-16-30	01-05-07-16-30-1	518.5	445.0	487.7	490.1	493.1	495.6	E	535.8	E	E	E	E	E	559.6	
SECURITY WHITE ROSE ELIM 7-7-16-30	01-07-07-16-30-1	518.8	442.3	E	488.9E	490.7	493.5	E	541.6	E	E	E	E	E	555.7	
WHITEHALL ET AL ELIM 8-7-16-30	01-08-07-16-30-1	517.1	441.7	E	490.7E	491.6	494.1	E	536.0	E	E	E	E	E	554.6	
CHAMPLIN ROCANVILLE 13-21-16-30	01-13-21-16-30-1	501.7	416.4	E	E	E	480.1E	E	510.1	E	E	E	E	E	534.3	
RIDDLE TIDEWATER ST MARTHE CR 1-6	01-01-06-17-30-1	481.6	382.5	E	E	E	456.2E	E	464.5	E	E	E	E	E	483.7	
SYLVITE STE MARTHE 14-5-17-30	40-14-05-17-30-1	495.9	396.2	E	E	E	477.9E	E	507.2	E	E	E	E	E	515.4	
P.C.S. ROCANVILLE 16-5-17-30	41-16-05-17-30-1	491.2	396.7	E	E	E	455.7E	E	480.0	E	E	E	E	E	496.5	
TOMBILL STE MARTHE 10-12	01-10-12-17-30-1	478.4	369.7	E	E	E	E	E	445.0E	E	E	E	E	E	459.6	
PCS MINING STE MARTHE 1-16-17-30	21-01-16-17-30-1	480.6	368.5	E	E	E	E	E	454.2E	E	E	E	E	E	463.9	
SYLVITE ST. MARTHE 13-14-17-30	31-13-14-17-30-1	479.2	367.3	E	E	E	E	E	447.4E	E	E	E	E	E	450.8	
NORANDA TOMBILL MARTHE 1-16-17-30	11-01-16-17-30-1	481.0	374.9	E	E	E	E	E	456.0E	E	E	E	E	E	463.3	
PCS MINING STE MARTHE 3-20-17-30	21-03-20-17-30-1	483.9	386.7	E	E	E	446.5E	E	469.4	E	E	E	E	E	474.3	
NORANDA TOMBILL MARTHE 4-20-17-30	21-04-20-17-30-1	487.6	386.5	E	E	E	454.2E	E	475.4	E	E	E	E	E	486.0	
P.C.S. ROCANVILLE 12-22-17-30	31-12-22-17-30-1	483.3	376.0	E	E	E	E	E	455.0E	E	E	E	E	E	459.5	
SYLVITE STE. MARTHE 13-22-17-30	21-13-22-17-30-1	483.0	371.9	E	E	E	E	E	446.0E	E	E	E	E	E	450.2	
NORANDA TOMBILL MARTH 16-22-17-30	41-16-22-17-30-1	479.3	367.9	E	E	E	E	E	430.4E	E	E	E	E	E	440.7	
PCS ROCANVILLE 6-23-17-30	41-06-23-17-30-1	478.2	363.7	E	E	E	420.0E	E	426.1	E	E	E	E	E	440.5	
SYLVITE ST. MARTHE 6-26-17-30	21-06-26-17-30-1	472.7	359.4	E	E	E	413.3E	E	425.8	E	E	E	E	E	438.9	

					RED JACKET FORMATION											
WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	RIERDON FORMATION	BURROWS BURROWS "B"	MEMBER BURROWS "A"	MOOSOMIN MEMBER	ROCANVILLE ROCANVILLE "C"	MEMBER ROCANVILLE "B"	ROCANVILLE "A"	LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
SYLVITE ST. MARTHE 11-25-17-30	31-11-25-17-30-1	425.7	306.6	E	E	E	E	E	360.9E	E	E	E	E	E	370.3	
SYLVITE ST. MARTHE 3-28-17-30	41-03-28-17-30-1	486.3	374.9	E	E	E	E	E	448.1E	E	E	E	E	E	459.6	
TOMBILL S A H WELBY 8-32	31-08-32-17-30-1	407.7	295.7	E	E	E	E	E	E	E	E	E	E	E	375.7E	
SYLVITE ST. MARTHE 10-34-17-30	01-10-34-17-30-1	413.9	290.3	E	E	E	E	E	E	E	E	E	E	E	361.2E	
MIRANDA-TOMBILL WELBY 14-36-17-30	41-14-36-17-30-1	484.2	362.1	E	E	E	E	E	416.8E	E	E	E	E	E	426.0	
IMP CDN-SUP MARTIN 1-3-12-31	01-01-03-12-31-1	585.8	600.5	649.0	691.3	701.6	714.1	E	749.2	E	772.1	E	780.9	E	825.1	818.4-848.9
TRICENT ET AL FLEMING 12-13-12-31	21-12-13-12-31-1	578.5	585.0	655.5	671.8	681.1	685.9	E	715.6	E	744.6	E	754.0	E	802.0	
PRECAM FEMING 5-15-12-31	31-05-15-12-31-1	582.6	594.0	643.3	684.0	694.8	697.7	E	733.0	E	757.0	E	767.7	E	813.7	
PCI FLEMING 16-34-12-31	31-16-34-12-31-1	574.8	567.7	614.0	651.0	660.1	662.8	E	720.0	E	724.0	E	740.7	E	778.0	
MARK MOOSOMIN 10-20-13-31	11-10-20-13-31-1	576.0	564.0	612.0	643.2	651.8	655.0	687.3	694.1	E	717.0	E	738.1	E	759.6	
B-R-G ROTAVE CR 16-22-13-31	01-16-22-13-31-1	576.4	558.7	614.2	638.9	646.5	649.2	E	692.5	E	701.6	E	725.1	E	762.0	
CAN SCURRY MOOSOMIN 5-28-13-31	01-05-28-13-31-1	576.8	560.2	610.1	636.6	643.0	646.0	676.0	685.0	E	707.0	E	734.2	E	752.0	
GRIDOIL TIDEWATER MOOSOMIN WC 16-4	01-16-04-14-31-1	563.9	539.5	582.8	611.7	618.1	620.9	651.7	657.5	E	679.6	E	689.2	E	708.4	
COLGAS ET AL MOOSOMIN 16-16-14-31	11-16-16-14-31-1	542.1	498.5	538.9	566.0	568.7	571.6	E	615.0	E	629.0	E	643.3	E	665.7	
CO-ENERCO VEC MOOSOMIN 16-20-14-31	41-16-20-14-31-1	563.1	528.8	563.5	595.0	599.7	602.6	628.8	644.6	E	658.3	E	673.2	E	690.5	
WESTMIN SAGEOIL MOOSOMIN 8-21-14-31	01-08-21-14-31-1	552.0	514.0	560.0	587.1	591.7	594.6	627.3	632.1	E	655.0	E	666.6	E	685.5	620.0-632.4
TRICENT ET AL MOOSOMIN 14-21-14-31	31-14-21-14-31-1	555.7	517.5	557.2	586.0	589.0	591.6	620.6	627.0	E	647.0	E	663.5	E	678.0	591.0-605.0
RIDDLE T.W. MOOSOMIN CR 5-26-14-31	01-05-26-14-31-1	538.7	482.6	537.7	562.1	567.5	570.0	602.9	605.9	E	624.8	E	637.6	E	655.3	
DOME ET AL MOOSOMIN 5-25-14-31	21-05-25-14-31-1	538.2	482.6	537.2	561.0	NOT PRES	567.5	594.5	604.6	E	624.0	E	639.0	E		
SUNCOR ET AL MOOSOMIN 2-28-14-31	21-02-28-14-31-1	553.1	516.0	556.4	582.4	588.1	591.0	614.8	621.7	E	644.9	E	665.0			
TRICENT ET AL MOOSOMIN 4-28-14-31	01-04-28-14-31-1	556.0	517.7	554.4	581.7	586.3	589.2	615.0	626.5	E	648.7	E	664.9	E	681.5	588.0-597.0, 599.0-607.0 649.0-689.0
TRICENT ET AL MOOSOMIN 6-28-14-31	21-06-28-14-31-1	552.0	514.0	553.0	581.0	585.0	588.0	613.3	623.0	E	650.0	E	659.7	E	678.0	582.0-595.6
SUNCOR ET AL MOOSOMIN 8-28-14-31	11-08-28-14-31-1	549.1	509.0	550.0	576.0	579.0	582.0	614.3	621.0	E	646.5	E	657.7	E	674.4	591.7-600.7
CDNO ET AL MOOSOMIN 11-28-14-31	11-11-28-14-31-1	552.5	512.1	551.2	579.0	583.0	585.9	E	624.0	E	645.1	E	661.7	E	675.0	591.5-606.3
TRICENT ET AL MOOSOMIN 1-29-14-31	11-01-29-14-31-1	559.5	521.5	558.8	588.0	589.9	592.9	619.4	631.0	E	653.2	E	668.5	E	688.2	
TRICENT ET AL MOOSOMIN 6-29-14-31	01-06-29-14-31-1	562.5	524.8	559.0	590.0	594.8	597.6	625.9	637.5	E	664.0	E	675.0	E	688.0	602.0-611.0
TRICENT ET AL MOOSOMIN 8-29-14-31	11-08-29-14-31-1	557.7	519.5	556.2	585.0	589.1	592.0	623.0	632.0	E	655.8	E	666.5	E	685.5	
TRICENT ET AL MOOSOMIN 10-29-14-31	11-10-29-14-31-1	560.0	524.6	560.0	591.3	595.9	598.7	628.0	635.0	E	662.0	E	670.5	E	690.0	
CPOG ET AL MOOSOMIN 6-30-14-31	01-06-30-14-31-1	566.0	531.9	561.8	597.4	604.4	607.2	E	652.6	E	673.6	E	682.0	E	705.0	
MAGNUM RED JACKET W 13-31-14-31	31-13-31-14-31-1	559.8	519.0	559.2	581.3	587.3	590.5									
TRICENT ET AL MOOSOMIN 8-32-14-31	41-08-32-14-31-1	556.7	512.0	551.0	576.3	582.1	585.0	610.0	622.0	E	643.3	E	658.8	E	675.7	587.4-602.2
CO-ENERCO VEC MOOSOMIN 6-33-14-31	11-06-33-14-31-1	550.8	508.7	550.0	574.1	579.9	582.7	608.0	617.0	E	641.0	E	654.7	E	675.0	578.0-592.0
TENNECO JORDAN MOOSOMIN 4-3-15-31	01-04-03-15-31-1	549.9	506.6	544.4	573.0	577.0	580.6	606.6	618.7	E	641.3	E	654.1	E	667.5	
SAGEOIL CR RED JACKET 12-3-15-31	41-12-03-15-31-1	548.1	502.0	540.0	566.0	570.8	573.2	E	620.0	E	652.9	E	647.6	E	661.2	
MAGNUM ET AL RED JACKET 7-5-15-31	31-07-05-15-31-1	550.0	515.8	531.5	579.0	585.1	587.8									
CAL-STAN RED JACKET 10-5-15-31	01-10-05-15-31-1	557.8	512.7	548.6	574.8	580.9	582.8	E	645.0	E	651.7	E	665.7	E	679.7	664.5-679.7
SAGEOIL CR WELWYN 3-6-15-31	01-03-06-15-31-1	565.6	534.1	557.0	592.3	596.3	598.2	E	654.0	E	673.2	E	685.0			
TRICENT ET AL RED JACKET 5-8-15-31	21-05-08-15-31-1	560.2	515.8	556.0	579.7	586.9	589.8	E	640.0	E	653.2	E	665.0	E	680.0	
VOYAGER CEDC ROCANVILLE 16-9-15-31	41-16-09-15-31-1	543.4	501.3	533.7	565.0	567.3	570.0	598.6	607.5	E	635.6	E	644.3	E	650.8	
VOYAGER CEDC ROCANVILLE 6-10-15-31	21-06-10-15-31-1	546.1	503.7	543.0	567.6	572.6	575.0	E	615.0	E	635.0	E	644.3	E	655.0	
CDNO ET AL WELWYN 4-15-15-31	31-04-15-15-31-1	542.2	497.3	529.3	557.0	560.0	565.3	593.2	599.2	E	623.9	E	639.5	E	646.2	
CDNO ET AL WELWYN 1-16-15-31	01-01-16-15-31-1	543.1	490.9	500.7	547.9	553.2	555.5	582.8	592.0	E	E	E	642.6	E	648.3	555.0-573.0
TRICENT ET AL ROCANVILLE 6-16-15-31	11-06-16-15-31-1	547.7	506.4	526.0	560.0	565.4	567.7	596.1	602.0	E	620.0	E	643.0	E	652.0	
CDNO ET AL WELWYN W 8-16-15-31	11-08-16-15-31-1	542.5	486.9	518.4	544.0	549.6	551.7	579.0	586.6	E	E	E	E	E	643.3	553.0-569.0
ARCO RED JACKET 14-17-15-31	01-14-17-15-31-1	549.9	511.1	542.2	569.7	575.5	577.6	E	629.1	E	640.4	E	649.8	E	656.8	572.0-591.0
ROCAN ROCANVILLE 13-21-15-31	31-13-21-15-31-1	542.4	485.1	516.6	548.3	552.6	555.3	E	601.7	E	617.2	E	627.9	E	632.8	
ROCAN ROCANVILLE CR 9-22-15-31	01-09-22-15-31-1	531.9	468.2	506.6	536.1	528.8	551.6	E	584.3	E	598.9	E	607.5	E	616.0	

WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	RIERDON FORMATION	RED JACKET FORMATION						LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
					BURROWS BURROWS "B"	MEMBER BURROWS "A"	MOOSOMIN MEMBER	ROCANVILLE ROCANVILLE "C"	MEMBER ROCANVILLE "B"	ROCANVILLE "A"						
ROCAN ROCANVILLE 13-23-15-31	01-13-23-15-31-1	529.7	468.2	505.1	520.9	525.6	526.1	E	580.0	E	597.7	E	606.6	E	612.3	
ROCAN ROCANVILLE 7-27-15-31	01-07-27-15-31-1	532.5	468.5	502.3	526.4	528.8	531.3	E	575.6	E	596.7	E	605.8	E	612.6	
ROCAN ROCANVILLE 13-27-15-31	01-13-27-15-31-1	532.6	470.3	509.6	528.8	532.5	534.9	E	588.3	E	599.8	E	608.1	E	612.3	
ROCAN ROCANVILLE 15-27-15-31	01-15-27-15-31-1	531.0	465.7	506.3	518.8	522.1	524.6	E	571.2	E	586.6	E	601.4	E	606.6	
ROCAN ROCANVILLE 1-28-15-31	01-01-28-15-31-1	536.6	475.5	508.1	533.4	537.1	539.5	E	586.6	E	605.3	E	618.7	E	623.6	
TRITON ROCANVILLE 5-28-15-31	01-05-28-15-31-1	540.4	485.2	516.0	548.6	552.9	555.3	E	599.9	E	615.7	E	626.2	E	629.4	
ROCAN ROCANVILLE 13-28-15-31	01-13-28-15-31-1	538.4	478.5	523.6	541.6	545.0	547.6	575.8	580.0	E	609.0	E	621.8	E	628.5	
RIDDLE OKALTA ROCANVILLE 16-31	01-16-31-15-31-1	541.0	483.6	524.3	546.8	551.6	553.5	E	579.1	E	615.1	E	625.8	E	632.2	
EMPIRE ST ROCANVILLE 14-32-15-31	01-14-32-15-31-1	539.5	477.0	509.3	536.9	539.5	541.9	E	570.9	E	601.1	E	619.0	E	623.3	
RIDDLE TW ROCANVILLE CR 16-32	01-16-32-15-31-1	527.9	468.5	500.8	526.7	532.2	534.0	E	572.6	E	595.6	E	611.1	E	618.1	
ROCAN ROCANVILLE 1-33-15-31	01-01-33-15-31-1	538.7	476.4	510.5	537.1	541.6	543.8	E	587.7	E	605.5	E	611.7	E	616.6	
TIDEWATER RIDDLE ROCANVILLE NO 12-33	01-12-33-15-31-1	534.3	468.2	500.5	526.9	527.9	530.3	E	580.3	E	609.3	E	612.3	E	617.3	
HUDSON ROCANVILLE 14-33	01-14-33-15-31-1	532.8	469.1	502.9	531.3	534.9	537.1	E	575.2	E	602.9	E	609.3	E	614.2	
PALMER ET AL ROCANVILLE 4-34-15-31	41-04-34-15-31-1	531.9	469.1	501.9	526.8	530.0	532.1	E	576.0	E	595.3	E	605.0	E	610.0	
CDNO ET AL ROCANVILLE 4-35-15-31	01-04-35-15-31-1	529.4	460.5	497.8	515.8	519.9	521.9	E	560.0	E	583.2	E	596.0	E	597.0	
ROCAN-ROCANVILLE 10-1-16-31	01-10-01-16-31-1	523.0	447.5	487.1	499.3	502.9	505.6	E	553.2	E	572.6	E	E	E	575.6	
TRITON ROCANVILLE 10-2-16-31	41-10-02-16-31-1	526.4	451.1	487.6	503.0	506.5	508.8	E	551.0	E	572.0	E	E	E	581.0	
MACEDON ET AL ROCANVILLE 14-2-16-31	41-14-02-16-31-1	526.0	452.0	487.0	502.0	506.0	510.3	E	553.0	E	570.0	E	E	E	580.9	
TRITON ROCANVILLE 15-2-16-31	01-15-02-16-31-1	525.7	451.6	490.3	503.6	506.9	509.3	E	541.0	E	572.0	E	E	E	579.8	
ROCAN ROCANVILLE 16-2-16-31	01-16-02-16-31-1	526.1	448.1	487.6	500.2	503.5	506.0	E	539.5	E	567.5	E	E	E	575.2	
ROCAN ROCANVILLE 16-3-16-31	01-16-03-16-31-1	527.6	454.5	489.5	509.3	512.7	515.0	E	563.0	E	576.7	E	588.3	E	591.0	
HUDSON ROCANVILLE 2-4	01-02-04-16-31-1	531.6	467.0	499.0	528.5	531.0	533.6	E	577.9	E	597.7	E	606.6	E	609.6	
HUDSON ROCANVILLE 4-4	01-04-04-16-31-1	534.6	468.8	499.9	527.6	530.7	533.1	E	573.0	E	600.8	E	607.8	E	611.7	
TRITON ROCANVILLE 5-4-16-31	01-05-04-16-31-1	535.7	472.5	505.7	532.0	535.3	537.9	566.5	571.0	E	603.0	E	611.5	E	616.0	
W H HUDSON RIDDLE ROCANVILLE 6-4	01-06-04-16-31-1	533.7	466.8	498.0	521.2	526.6	527.0	554.7	565.1	E	605.5	E	609.3	E	613.0	
HUDSON ET AL ROCANVILLE CROWN 10-4	01-10-04-16-31-1	530.3	460.9	496.1	516.9	520.0	522.6	552.0	558.6	E	591.9	E	603.5	E	605.6	
HUDSON ROCANVILLE CR 12-4	01-12-04-16-31-1	529.7	469.6	502.9	529.4	532.5	536.6	560.8	565.9	E	595.3	E	609.0	E	613.3	
TRITON ROCANVILLE 1-5-16-31	01-01-05-16-31-1	537.5	471.0	505.2	529.9	533.0	535.1	560.5	566.0	E	605.6	E	611.6	E	616.8	
HUDSON ROCANVILLE 2-5	01-02-05-16-31-1	537.3	473.1	506.0	536.9	538.9	541.0	566.3	569.7	E	600.2	E	615.1	E	616.9	
TRITON ROCANVILLE 3-5-16-31	41-03-05-16-31-1	539.5	475.5	508.0	537.0	540.0	542.1	E	582.5	E	606.6	E	615.5	E	620.0	
TRITON ROCANVILLE 4-5-16-31	01-04-05-16-31-1	542.6	477.0	512.6	532.7	535.5	537.6	567.0	570.0	E	E	E	605.0	E	625.2	
HUDSON ROCANVILLE 6-5-16-31	01-06-05-16-31-1	539.8	476.1	509.9	539.8	543.5	545.6	576.9	582.2	E	606.1	E	618.3	E	620.0	
TRITON ROCANVILLE 7-5-16-31	01-07-05-16-31-1	536.6	474.5	508.0	536.8	540.1	542.2	571.5	575.0	E	603.9	E	615.2	E	619.0	
HUDSON ROCANVILLE 8-5	01-08-05-16-31-1	536.2	474.6	507.8	534.6	538.3	540.6	567.2	573.6	E	601.7	E	615.4	E	618.4	
TRITON ROCANVILLE 9-5-16-31	01-09-05-16-31-1	535.1	475.1	508.8	535.0	539.9	542.0	568.0	578.0	E	605.3	E	615.6	E	620.7	
HUDSON ROCANVILLE 10-5	01-10-05-16-31-1	537.4	478.4	509.6	536.8	540.1	542.5	578.8	580.6	E	606.6	E	603.0	E	626.3	
R A CHAPMAN ROCANVILLE 11-5-16-31	01-11-05-16-31-1	538.6	476.1	522.1	534.6	538.6	540.7	572.6	577.3	E	605.9	E	E	E	627.3	
FREEHOLDERS ROCANVILLE 12-5	01-12-05-16-31-1	541.5	479.5	525.8	540.1	543.5	545.6	578.5	585.2	E	606.6	E	621.8	E	625.5	
H E RIDDLE C P R NO 15-5	01-15-05-16-31-1	536.5	476.0	523.0	535.5	538.6	540.7	569.6	573.0	E	605.9	E	617.0	E	624.8	
TRITON ROCANVILLE 16-5-16-31	01-16-05-16-31-1	533.7	471.5	518.0	533.0	537.0	539.0	574.0	578.8	E	603.0	E	615.0	E	618.0	
ROCAN ROCANVILLE 6-6-16-31	01-06-06-16-31-1	545.7	490.1	535.8	550.8	554.7	557.2	588.9	591.0	E	628.5	E	632.8	E	638.8	
VANNER ET AL ROCANVILLE 3-10-16-31	31-03-10-16-31-1	528.9	461.0	491.0	514.0	520.0	522.5	E	561.0	E	586.9	E	E	E	605.0	
ROCANVILLE 4-10-16-31	01-04-10-16-31-1	526.5	457.0	486.1	515.1	518.2	520.6	E	564.2	E	591.3	E	E	E	605.6	
VANNER ET AL ROCANVILLE 5-10-16-31	41-05-10-16-31-1	529.7	460.0	505.0	515.6	521.0	523.3	E	565.0	E	586.1	E	E	E	605.9	
VANNER ET AL ROCANVILLE 6-10-16-31	01-06-10-16-31-1	529.5	459.5	495.2	516.0	519.7	522.0	E	557.0	E	585.7	E	E	E	603.2	
VANNER ET AL ROCANVILLE 7-10-16-31	01-07-10-16-31-1	522.5	456.0	490.1	513.0	517.2	519.8	E	560.0	E	580.7	E	E	E	597.2	
D AND H LARIO ROCANVILLE 12-10-16-31	01-12-10-16-31-1	527.6	456.9	480.8	513.9	516.9	518.8	E	564.3	E	582.8	E	E	E	596.2	
TRITON ET AL ROCANVILLE 2-11-16-31	01-02-11-16-31-1	526.8	447.9	480.1	498.5	502.0	506.0	E	565.0	E	573.6	E	E	E	575.7	

WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	RIERDON FORMATION	RED JACKET FORMATION BURROWS MEMBER BURROWS "B"	MEMBER BURROWS "A"	MOOSOMIN MEMBER	ROCANVILLE ROCANVILLE "C"	MEMBER ROCANVILLE "B"	ROCANVILLE "A"	LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
TRITON ROCANVILLE 3-11-16-31	01-03-11-16-31-1	525.1	452.3	487.0	503.0	506.1	508.2	E	539.5	E	567.0	E	E	E	580.3	
ROCAN-ROCANVILLE 6-11-16-31	01-06-11-16-31-1	526.3	449.3	488.9	502.9	506.0	508.6	E	539.5	E	567.2	E	E	E	575.2	
TRITON ET AL ROCANVILLE 7-11-16-31	31-07-11-16-31-1	526.9	449.0	492.0	501.5	505.0	507.1	E	540.3	E	569.0	E	E	E	575.7	
ROCAN ROCANVILLE 8-11-16-31	01-08-[illegible]6-31-1	525.7	448.1	495.2	498.0	501.4	503.5	E	546.2	E	565.7	E	E	E	572.7	
ROCAN ROCANVILLE CR. 10-11-16-31	01-10-11-16-31-1	526.0	448.1	496.5	497.4	501.4	503.5	E	545.6	E	566.6	E	E	E	576.1	
CONO ET AL ROCANVILLE 11-11-16-31	21-11-11-16-31-1	525.5	450.5	495.0	504.3	508.0	510.0	E	546.0	E	578.0	E	E	E	581.3	
ROCAN ROCANVILLE DRONE 12-11-16-31	01-12-11-16-31-1	526.6	450.8	487.1	504.1	507.8	509.9	E	551.7	E	580.9	E	E	E	585.8	
ROCAN-ROCANVILLE 16-11-16-31	01-16-11-16-31-1	522.1	451.4	495.3	502.9	506.3	508.7	E	539.2	E	571.2	E	E	E	580.0	
ROCAN ROCANVILLE 6-12-16-31	01-06-12-16-31-1	526.3	448.4	492.9	498.7	502.0	504.1	E	548.0	E	568.1	E	E	E	575.3	
ROCAN ROCANVILLE CR. 12-12-16-31	01-12-12-16-31-1	521.8	446.5	495.0	495.2	499.6	501.1	E	545.1	E	564.5	E	E	E	571.5	
ROCAN-ROCANVILLE 2-13-16-31	01-02-13-16-31-1	520.6	443.8	E	496.7R	496.2	498.6	E	541.9	E	567.5	E	E	E	571.8	
ANDANAC ROCANVILLE 2-14-16-31	01-02-14-16-31-1	522.4	440.6	493.2	498.7	501.7	504.1	E	548.9	E	575.0	E	E	E	582.8	
DPO B. ROCANVILLE 13-14-16-31	01-13-14-16-31-1	523.8	442.6	E	E	E	501.7R	E	529.7	E	556.6	E	E	E	561.4	
CANUS PLC BP ROCAN 2-16-16-31	01-02-16-16-31-1	526.3	495.1	501.6	512.7	515.7	517.9	E	557.2	E	577.9	E	E	E	595.1	
CANUS PLC BP ROCAN 16-17-16-31	01-16-17-16-31-1	526.6	453.9	E	510.2R	512.1	514.5	E	548.8	E	572.6	E	E	E	588.0	
DPO W. ROCANVILLE 6-18-16-31	01-06-18-16-31-1	537.7	476.6	E	535.8R	538.0	540.1	E	579.7	E	602.0	E	612.6	E	616.0	
ASHLAND TB ROCANVILLE 16-18-16-31	01-16-18-16-31-1	531.0	460.6	516.8	517.6	521.2	525.6	E	552.3	E	578.5	E	E	E	599.5	
FRANCANA ET AL ROCANVILLE 6-20-16-31	01-06-20-16-31-1	525.3	454.5	502.9	504.7	507.8	510.2	E	543.2	E	570.0	E	E	E	585.8	
ASHLAND TB ROCANVILLE 14-20-16-31	01-14-20-16-31-1	525.3	449.3	E	501.1	502.6	504.7	E	536.4	E	565.6	E	E	E	569.1	
TRITON ROCANVILLE 5-22-16-31	01-05-22-16-31-1	525.8	449.0	E	E	E	512.1R	E	529.4	E	562.1	E	E	E	568.5	
CO-OP ET AL ROCANVILLE 5-25-16-31	01-05-25-16-31-1	525.2	444.7	E	E	E	505.5R	E	526.2	E	556.0	E	E	E	565.3	
SECURITY WHITE ROSE ELIM 6-26-16-31	01-06-26-16-31-1	510.7	436.3	E	E	E	497.4R	E	512.4	E	540.0	E	E	E	548.3	
DOME ROCANVILLE 16-27-16-31	01-16-27-16-31-1	520.7	436.2	E	E	E	517.0R	E	526.0	E	E	E	E	E	540.5	
DOME PROMO ROCANVILLE 6-28-16-31	01-06-28-16-31-1	525.0	447.5	E	E	499.0R	501.7	E	531.0	E	556.3	E	E	E	561.1	
ROCAN ROCANVILLE CRN 10-29-16-31	01-10-29-16-31-1	526.6	443.5	E	E	E	E	E	538.3R	E	557.3	E	E	E	561.4	
ASHLAND LLBC ROCANVILLE 12-30-16-31	01-12-30-16-31-1	526.9	449.3	E	E	E	E	E	542.3R	E	565.4	E	E	E	576.7	
SECURITY W R TANTALLON 3-32-17-31	01-03-32-17-31-1	518.5	436.0	E	E	E	476.0R	E	495.3	E	E	E	E	E	516.6	
CDN SUP MOOSOMIN 11-8-13-32	21-11-08-13-32-1	587.1	607.8	622.7	688.9	697.2	700.1	732.6	737.7	E	776.8	E	785.0	E	820.0	
GULF RED JACKET SOUTH 1-9-13-32	11-01-09-13-32-1	585.5	596.0	610.0	681.9	691.5	694.5	728.6	731.8	E	755.0	E	772.9	E	816.0	
CENTRAL DEL RIO RED JACKET NO 6-19	41-06-19-13-32-1	601.1	595.3	611.4	679.1	687.0	689.8	721.2	728.2	E	756.8	E	764.7	E	796.8	628.2-679.1, 673.0-679.1 686.0-702.6, 771.1-788.0
CNW ET AL RED JACKET 13-29-13-32	01-13-29-13-32-1	586.4	581.0	600.0	665.8	674.8	678.0	E	725.0	E	744.0	E	755.0			
TRICENT ET AL RED JACKET 16-32-13-32	41-16-32-13-32-1	580.3	574.0	602.0	649.1	656.8	659.9	E	718.0	E	728.7	E	747.9	E	770.3	658.0-671.0
TRICENT ET AL RED JACKET 16-33-13-32	31-16-33-13-32-1	579.8	570.9	591.7	650.2	659.3	662.3	E	707.9	E	727.3	E	738.0	E	773.8	
ARCO SCURRY MOOSOMIN 16-1-14-32	01-16-01-14-32-1	583.7	569.6	587.9	643.1	649.8	653.2	E	688.5	E	717.2	E	726.8	E	750.5	645.0-705.6
TRICENT ET AL RED JACKET 10-3-14-32	31-10-03-14-32-1	581.7	575.5	608.2	642.8	650.2	653.8	E	698.9	E	723.0	E	734.4	E	760.5	
TRICENT ET AL RED JACKET 13-3-14-32	31-13-03-14-32-1	586.5	578.0	610.5	648.1	655.7	658.7	E	709.3	E	735.0	E	746.0			
TRICENT ET AL RED JACKET 2-6-14-32	31-02-06-14-32-1	581.0	574.3	595.0	648.2	656.6	659.5	E	705.0	E	730.0	E	738.8	E	759.0	664.0-673.0
TRICENT ET AL RED JACKET 4-6-14-32	31-04-06-14-32-1	577.9	568.7	597.6	641.8	650.0	653.0	E	713.0	E	725.1	E	751.0	E	775.9	645.0-676.0
TRICENT ET AL RED JACKET 5-6-14-32	21-05-06-14-32-1	585.6	576.6	605.0	648.6	656.6	659.2	E	716.0	E	739.8	E	748.0	E	780.9	647.0-676.0
NORWICH ET AL RED JACKET 6-6-14-32	41-06-06-14-32-1	582.0	575.0	592.0	646.0	655.0	657.6									
TRICENT ET AL RED JACKET 7-6-14-32	30-07-06-14-32-1	580.9	576.0	592.2	650.5	658.5	661.6	E	716.9	E	735.7	E	739.8			
TRICENT ET AL RED JACKET 8-6-14-32	31-08-06-14-32-1	582.1	576.0	597.0	649.0	657.2	660.3	E	701.1	E	731.0	E	737.5	E	770.0	
NORWICH ET AL RED JACKET 9-6-14-32	31-09-06-14-32-1	582.4	571.2	592.0	643.0	650.7	655.6									
TRICENT ET AL RED JACKET 10-6-14-32	21-10-06-14-32-1	586.8	576.6	600.0	648.2	656.0	659.5	E	725.2	E	735.1	E	750.6	E	776.0	664.0-671.0
TRICENT ET AL RED JACKET 11-6-14-32	01-11-06-14-32-1	586.3	579.0	599.0	651.3	659.8	662.0	E	726.0	E	752.0	E	749.0	E	777.1	
TRICENT ET AL RED JACKET 11-67-14-32	02-11-06-14-32-1	586.2	579.0	599.0	651.4	659.0	662.2									
TRICENT ET AL RED JACKET 12-6-14-32	11-12-06-14-32-1	581.1	581.3	601.8	655.0	665.0	667.8	E	723.0	E	752.9	E	762.5	E	778.0	646.0-657.0, 662.0-671.0

WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	RIERDON FORMATION	RED JACKET FORMATION						LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
					BURROWS MEMBER BURROWS "B"	MEMBER BURROWS "A"	MOOSOMIN MEMBER	ROCANVILLE ROCANVILLE "C"	MEMBER ROCANVILLE "B"	ROCANVILLE "A"						
TRICENT ET AL RED JACKET 14-6-14-32	11-14-06-14-32-1	582.1	576.5	597.3	653.8	662.0	665.0	E	723.9	E	727.5	E	740.3			
HERBACO ET AL RED JACKET 15-6-14-32	10-15-06-14-32-1	586.0	575.3	590.2	640.4	657.3	660.0									
TRICENT ET AL RED JACKET 16-6-14-32	41-16-06-14-32-1	585.6	573.9	595.0	645.1	653.0	655.9	E	708.1	E	729.2	E	730.3	E	770.7	
CNW RED JACKET 1-5-14-32	41-01-05-14-32-1	586.5	579.6	609.0	652.3	660.0	662.7	E	711.3	E	730.0	E	751.8	E	785.0	
CNW RED JACKET 3-5-14-32	01-03-05-14-32-1	580.2	574.2	607.3	653.7	662.5	665.2	E	712.6	E	734.0	E	747.0	E	783.0	655.0-658.6, 660.5-661.5
CNW RED JACKET 8-5-14-32	01-08-05-14-32-1	584.9	580.2	609.0	655.7	663.8	667.0	E	716.3	E	735.2	E	750.0	E	785.0	657.0-682.0
DOME ET AL RED JACKET 16-7-14-32	01-16-07-14-32-1	587.2	576.5	605.0	653.1	663.1	666.1	E	728.5	E	739.8	E	760.4			
TRICENT ET AL RED JACKET 1-9-14-32	11-01-09-14-32-1	586.9	577.4	610.2	655.0	660.5	665.5	E	717.7	E	730.3	E	760.0	E	770.8	
HERBACO ET AL RED JACKET 3-10-14-32	21-03-10-14-32-1	582.5	575.7	605.2	647.0	653.0	657.7									
TRICENT ET AL RED JACKET 4-10-14-32	21-04-10-14-32-1	586.8	573.8	609.0	644.7	652.0	655.1	E	715.0	E	734.5	E	737.8	E	780.7	
HERBACO ET AL RED JACKET 5-10-14-32	21-05-10-14-32-1	583.7	577.3	601.5	646.2	655.0	658.1	E	711.0	E	734.0	E	735.0			
TRICENT ET AL REDJACKET 6-10-14-32	21-06-10-14-32-1	582.0	578.9	604.0	640.0	653.9	657.0	E	714.0	E	733.0	E	742.0	E		
TRICENT ET AL RED JACKET 9-11-14-32	21-09-11-14-32-1	581.2	566.7	595.0	636.3	643.1	646.1	670.5	686.5	E	708.2	E	721.3	E	749.0	
TRICENT ET AL MOOSOMIN 11-12-14-32	41-11-12-14-32-1	585.5	569.3	596.0	641.3	648.8	651.8	686.0	690.0	E	712.4	E	722.9	E	740.5	
WESTMILL ET AL RED JACKET 1-14-14-32	41-01-14-14-32-1	586.9	571.0	601.0	639.0	644.9	650.0									
BURGAN HAMM RED JACKET 4-14-14-32	01-04-14-14-32-1	581.1	569.1	602.5	636.0	641.7	644.6	E	702.9	E	710.3	E	730.9	E	748.0	
WOODSIDE ET AL RED JACKET 7-14-14-32	01-07-14-14-32-1	582.5	570.0	607.0	639.5	646.1	649.3	E	702.9	E	708.8	E	728.0	E	749.6	
SRO RED JACKET 16-14-14-32	31-16-14-14-32-1	586.1	562.0	605.0	631.2	638.4	641.3	E	706.5	E	710.0	E	723.0	E	765.0	
TRICENT ET AL RED JACKET 3-15-14-32	11-03-15-14-32-1	584.5	572.5	601.6	639.7	648.0	651.0	E	E	E	774.6	E	730.0	E	757.8	
TRICENT ET AL RED JACKET 5-19-14-32	31-05-19-14-32-1	587.6	575.7	606.6	649.8	658.9	662.0	692.8	701.6	E	724.9	E	733.5	E	766.7	
CONO ET AL RED JACKET 7-22-14-32	21-07-22-14-32-1	582.5	565.9	589.0	638.3	641.8	642.6	E	708.0	E	710.7	E	725.0	E	765.3	
SASKOIL WESTMIN REDJACKET 6-24-14-32	01-06-24-14-32-1	578.0	554.9	597.5	626.0	631.1	636.1	E	675.2	E	686.0	E	709.6	E	750.0	626.0-644.0, 700.0-709.0
RIDDLE TW REDJACKET CR 5-34-14-32	01-05-34-14-32-1	586.3	560.2	588.3	626.8	632.5	635.5	666.5	673.5	E	697.6	E	709.3	E	725.4	
TRICENT ET AL RED JACKET 7-36-14-32	21-07-36-14-32-1	580.8	555.9	591.0	621.3	629.8	632.8	660.0	669.3	E	698.5	E	711.3	E	723.5	
TIDE WATER EAST WAPELLA CROWN NO 4-6	01-04-06-15-32-1	595.8	579.1	611.7	650.4	659.0	662.0	691.3	708.6	E	725.6	E	736.7	E	767.2	675.1-731.2
DEVON PALMER CORTVILL 13-6-15-32	01-13-06-15-32-1	594.1	573.0	626.7	643.1	650.7	653.5	E	686.1	E	718.7	E	729.7	E	762.0	
RICH WES CPOG ROCANVILLE 4-19-15-32	01-04-19-15-32-1	592.2	561.1	E	E	E	668.4E	672.4	682.4	E	706.7	E	715.0	E	751.0	
HERBACO TOBL CORTVILL 15-19-15-32	41-15-19-15-32-1	592.0	560.0	E	E	627.0E	629.6	E	680.6	E	700.0	E	710.0			
TW CDR ROCANVILLE CR 9-20-15-32	01-09-20-15-32-1	566.9	534.5	574.2	588.0	595.6	597.7	626.4	654.0	E	657.6	E	673.0	E	688.0	
HERBACO TOBL CORTVILL 14-33-15-32	31-14-33-15-32-1	570.9	519.0	E	E	E	611.1E	E	620.0	E	648.7	E	668.0			
CANADIAN SUPERIOR WAPELLA 11-3-16-32	11-11-03-16-32-1	560.3	518.8	E	E	E	610.0E	619.8	626.0	E	648.0	E	660.0	E	666.3	
OCEAN ROCANVILLE CR 11-6-16-32	01-11-06-16-32-1	586.1	546.5	596.2	606.2	612.3	614.0	E	E	E	656.6	E	680.5	E	695.7	
MOBIL ROCANVILLE WEST 4-9-16-32	21-04-09-16-32-1	573.1	525.0	568.5	580.0	585.7	587.3	610.9	625.4	E	643.0	E	661.5	E	678.5	
CONO ET AL ROCANVILLE W 16-21-16-32	11-16-21-16-32-1	560.9	489.3	535.0	541.0	545.9	548.0	E	620.0	E	602.0	E	635.3	E	640.6	
CANUS P L C B P ROCAN 2-22-16-32	01-02-22-16-32-1	556.9	487.6	E	548.6	549.9	552.3	E	600.5	E	616.6	E	628.5	E	650.9	
CONO ET AL ROCANVILLE W 12-22-16-32	31-12-22-16-32-1	559.0	488.6	560.1	561.0	565.1	567.2	E	610.0	E	626.7	E	629.2	E	652.5	
CONO BARR ROCANVILLE 13-22-16-32	31-13-22-16-32-1	558.2	491.6	542.6	549.2	554.0	556.1	E	620.0	E	626.7	E	639.0	E	667.6	
CDN-SUP WAPELLA 11-26-16-32	41-11-26-16-32-1	538.2	448.7	E	E	E	E	E	565.0	E	585.6	E	590.0	E	605.3	
CANUS PLC BP ROCAN 2-27-16-32	01-02-27-16-32-1	548.9	488.0	E	545.0	550.5	552.0	E	580.3	E	620.9	E	632.0	E	637.6	
CONO ET AL ROCANVILLE 1-28-16-32	11-01-28-16-32-1	550.0	489.0	542.4	550.0	555.9	558.0	E	625.0	E	627.9	E	640.0	E	651.0	
ASHLAND LLOE ROCANVILLE 12-2-17-32	01-12-02-17-32-1	532.2	456.5	481.5	502.3	507.0	509.9	530.9	546.1	E	566.9	E	E	E	580.3	
FRANCANA ETAL ROCANVILLE 10-15-17-32	01-10-15-17-32-1	527.9	443.0	466.6	490.7	496.1	496.2	527.3	532.2	E	556.0	E	E	E	566.0	
ASHLAND TB ROCANVILLE W 10-16-17-32	41-10-16-17-32-1	530.4	446.1	470.6	497.1	501.7	505.5	E	530.9	E	550.4	E	E	E	569.3	
CAL-STAN TW CANNINGTON 4-20-17-32	01-04-20-17-32-1	545.9	457.0	482.2	509.1	514.5	516.3	E	540.2	E	559.5	E	E	E	589.5	
ASHLAND LLOE ROCANVILLE 16-29-17-32	01-16-29-17-32-1	527.3	441.6	E	E	E	519.1E	E	537.1	E	548.9	E	E	E	558.6	
TOMM A WAKOTA 10-3-12-33	01-10-03-12-33-1	610.1	671.8	762.2	771.4	777.5	780.9	E	800.3	E	867.3	867.5	870.8	913.3	939.3	
BENSON MONTIN GREER RIGA CROWN 10-14	01-10-14-13-33-1	585.4	600.2	616.9	688.2	698.6	701.6	E	761.6	E	769.0	E	780.0	885.0	888.3	
CNW WAPELLA 16-15-13-33	01-16-15-13-33-1	587.2	605.4	660.3	694.1	703.0	706.3	E	744.9	E	787.0	E	791.0	E	872.8	

					RED JACKET FORMATION											
WELL NAME	WELL LOCATION	K.B.	[illegible] FORMATION	RIERDON FORMATION	BURROWS BURROWS "B"	MEMBER BURROWS "A"	[illegible] MEMBER	ROCANVILLE ROCANVILLE "C"	MEMBER ROCANVILLE "B"	ROCANVILLE "A"	LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
[illegible] NORTH [illegible] EARLSWOOD 13-18	01-13-18-13-33-1	601.7	630.3	648.6	720.1	735.2	738.2	E	770.5	E	802.2	819.0	821.1	864.1	880.9	
CDN WAPELLA 8-31-13-33	01-08-31-13-33-1	596.4	613.8	695.8	702.1	709.3	712.0	E	753.2	E	775.0	E	792.0	833.3	839.0	
[illegible] RED JACKET CR 8-36-13-33	01-08-36-13-33-1	560.8	561.8	592.2	642.5	652.6	655.6	E	716.1	E	722.6	E	731.5	E	774.2	
CDN WAPELLA 3-9-14-33	01-03-09-14-33-1	597.9	586.7	666.5	680.6	689.0	692.7	E	751.3	E	751.0	E	772.3	E	807.0	
[illegible] ET AL [illegible] 14-11-14-33	01-14-11-14-33-1	587.4	586.4	632.0	662.2	672.1	675.5	E	713.0	E	738.7	E	751.6			
[illegible] ET AL [illegible] 6-14-14-33	01-06-14-14-33-1	587.4	582.0	641.6	658.1	665.2	668.3	699.0	706.2	E	746.0	E	748.0	E	789.3	
[illegible] ET AL [illegible] 10-14-14-33	21-10-14-14-33-1	589.0	583.2	635.0	659.9	668.0	675.9	700.0	708.0	E	741.9	E	750.0	E		
[illegible] ET AL [illegible] 12-14-14-33	41-12-14-14-33-1	586.4	591.9	637.0	658.2	667.0	670.1	703.0	709.0	E	751.8	E	744.0			
[illegible] CR [illegible] 2-15-14-33	41-02-15-14-33-1	586.0	586.8	640.6	667.5	675.0	678.0	705.6	710.0	E	751.4	E	757.8			
[illegible] CR [illegible] 6-15-14-33-1	01-06-15-14-33-1	590.7	583.0	638.0	661.6	671.4	673.0	E	727.0	E	E	E	760.3			
[illegible] [illegible] 8-15-14-33	41-08-15-14-33-1	589.8	585.1	624.0	661.9	670.0	673.0	702.4	710.3	E	759.7	E	748.3			
CDN WAPELLA 1-18-14-33	01-01-18-14-33-1	592.6	580.9	E	E	E	695.70	E	722.0	E	749.8	E	760.4	E	868.0	
[illegible] CENTRAL EARLSWOOD 1-19-14-33	01-01-19-14-33-1	591.6	590.7	E	E	E	694.33	717.8	725.0	E	749.8	E	763.8	E	881.6	
[illegible] ET AL WAPELLA 12-19-14-33	01-12-19-14-33-1	591.6	595.9	E	E	E	695.28	717.5	725.4	E	748.6					
[illegible]-JORDAN-CP WAPELLA 10-21-14-33	01-10-21-14-33-1	591.0	579.6	E	E	E	706.58	709.0	716.3	E	740.7	E	749.2			
[illegible] TIDEWATER [illegible] 9-22	01-09-27-14-33-1	589.5	586.9	620.3	661.4	669.0	675.3	702.0	710.0	E	754.0	E	760.1	E	779.6	632.0-658.7, 669.2-675.6 772.7-787.1
[illegible] CDN-WAPELLA 13-20-14-33	01-13-20-14-33-1	589.2	582.2	E	E	E	687.88	706.1	712.6	E	736.9	E	746.6			
[illegible] ET AL [illegible] 15-26-14-33	31-15-26-14-33-1	587.6	572.9	619.9	649.8	658.4	662.0	692.5	701.5	E	725.0	E	731.0	E	760.0	
D AND R [illegible] 12-27-14-33	01-12-27-14-33-1	590.7	580.2	651.7	659.6	666.9	670.6	705.3	710.0	E	735.7	E	742.5	E	778.0	
[illegible] WAPELLA 2-28-14-33	01-02-28-14-33-1	591.3	588.4	653.1	665.0	671.3	674.6	706.2	714.0	E	737.0					
[illegible] JORDAN E WAPELLA 1-29-14-33	01-01-29-14-33-1	591.9	598.3	664.7	668.7	677.3	680.9	715.1	719.0	E	746.2					
[illegible] WAPELLA CR 4-29-14-33	01-04-29-14-33-1	592.9	605.0	656.8	676.1	684.0	687.7	716.0	726.2	E	750.7					
[illegible] FERGUSON WAPELLA 12-30-14-33	01-12-30-14-33-1	589.5	607.5	666.9	681.8	689.5	692.5	721.0	727.0	E	753.8					667.4-678.7
[illegible] ET AL S. WAPELLA 15-30-14-33	01-15-30-14-33-1	595.5	602.6	655.0	673.0	679.9	685.0	715.0	722.3	E	757.7	E	762.0	E	798.0	
[illegible] CANDO CORP WAPELLA 7-32	01-07-32-14-33-1	592.0	588.5	637.3	660.0	668.7	672.7	706.0	712.6	E	726.4	E	744.9	E	786.9	
[illegible] TIDEWATER WAPELLA 5-2	20-05-02-15-33-1	585.4	579.1	627.9	647.1	653.0	657.1	688.2	696.5	E	722.7	E	731.5	E	769.3	
[illegible] NORTH WAPELLA 13-8-15-33	01-13-08-15-33-1	587.7	586.1	631.2	653.8	660.0	664.2	702.9	705.0	E	729.1	E	738.8			
[illegible] ET AL WAPELLA 13-12-15-33	41-13-12-15-33-1	595.4	573.2	618.6	642.6	648.4	651.6	E	705.5	E	723.0	E	731.0	E	762.2	660.3-671.0
[illegible] ET AL [illegible] 5-12-15-33	21-05-13-15-33-1	595.3	576.0	617.5	636.4	642.3	645.0	E	685.6	E	709.0					
[illegible] PALMER WAPELLA 11-16-15-33	01-11-16-15-33-1	594.7	571.8	627.6	648.9	655.6	658.7	690.1	697.6	E	721.2	E	730.9	E	768.1	
NORTH AMERICAN WAPELLA 12-17-15-33	01-12-17-15-33-1	594.1	582.2	640.7	652.9	659.9	662.9	E	706.7	E	727.3					
[illegible] [illegible] 6-22-15-33	01-06-22-15-33-1	602.0	573.0	625.8	644.7	647.5	650.0	E	722.0	E	738.4	E	746.0	767.0	771.0	653.0-668.0
[illegible] NORTH WAPELLA 11-35-15-33	01-11-35-15-33-1	596.4	563.0	601.7	625.1	630.9	633.7	666.0	670.6	E	697.1	E	709.0	E	726.9	
[illegible] ET AL ROCANVILLE 6-10-16-33	01-06-10-16-33-1	598.9	575.0	597.5	634.7	640.0	642.1	E	680.5	E	705.6	E	722.0	E	735.8	
[illegible] [illegible] [illegible] CR 9-12-17-33	01-09-12-17-33-1	566.4	489.2	531.3	540.4	545.0	547.4	E	595.3	E	609.6	E	E	E	622.4	
[illegible] NO. 2 [illegible] 1-14-17-33	01-01-14-17-33-1	518.8	494.4	543.6	546.7	551.4	553.3	E	606.6	E	616.9	E	E	E	622.7	
[illegible] NO. 1 [illegible] 13-22-17-33	01-13-22-17-33-1	560.5	498.3	544.4	552.9	559.6	561.4	E	609.6	E	623.6	E	E	E	627.0	
[illegible] NO. 3 [illegible] 14-26-17-33	01-14-26-17-33-1	562.4	479.8	524.9	526.1	531.3	533.4	E	583.4	E	595.2	E	E	E	605.6	
[illegible] [illegible] [illegible] 1-29-17-33	01-01-29-17-33-1	501.7	507.0	557.2	559.6	563.9	566.0	E	607.0	E	642.5	E	E	E	651.1	
[illegible] NO. 4 [illegible] 13-29-17-33	30-13-29-17-33-1	585.2	585.7	548.6	551.1	556.3	558.4	E	609.6	E	625.5	E	E	E	643.1	
[illegible] RED JACKET [illegible] 6-25-13-1	21-06-25-13-01-2	614.2	640.0	751.3	757.0	764.0	767.5	E	788.2	E	866.0	833.1	845.0	871.0	880.9	744.0-782.2
[illegible] SOUTH WAPELLA NO 13-10	01-13-10-14-01-2	608.4	622.1	E	E	E	734.08	734.1	760.5	E	782.4					756.4-770.5
[illegible] AND ASSOCIATES WAPELLA NO 1	01-16-19-14-01-2	602.6	615.7	E	E	E	735.08	E	752.9	E	775.4	781.3	798.6	838.2	851.0	
[illegible] SOUTH WAPELLA 11-23-14-1	01-11-23-14-01-2	597.4	680.8	E	E	E	722.46	E	745.2	E	786.6	780.0	785.2			753.6-763.1
[illegible] ET AL WAPELLA 15-25-14-1	01-15-25-14-01-2	592.2	595.1	E	E	E	698.08	721.2	728.5	E	747.4	781.1	785.0			
CDN WAPELLA 11-26-14-1	01-11-26-14-01-2	599.5	611.6	E	E	701.46	703.0	735.0	743.3	E	746.7	E	788.0			
[illegible] WAPELLA 14-26-14-1	01-14-26-14-01-2	597.0	606.5	E	E	E	706.48	720.0	738.1	E	760.8	E	774.0			751.0-759.6

WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	RIERDON FORMATION	RED JACKET FORMATION BURROWS BURROWS "B"	MEMBER BURROWS "A"	MOOSOMIN MEMBER	ROCANVILLE ROCANVILLE "C"	MEMBER ROCANVILLE "B"	ROCANVILLE "A"	LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
CNW WAPELLA 15-26-14-1	01-15-26-14-01-2	596.4	601.0	E	E	E	702.3E	728.9	735.1	E	759.5	E	773.5			
TENNECO-JORDAN WAPELLA 16-26-14-1	01-16-26-14-01-2	596.1	601.7	E	E	E	700.4E	725.4	734.0	E	752.6					
FOSSIL ET AL WAPELLA 6-27-14-1	31-06-27-14-01-2	604.1	617.0	E	708.3E	712.1	715.0	E	757.7	E	776.0	E	794.0			
FOSSIL DOME WAPELLA 11-27-14-1	01-11-27-14-01-2	602.2	611.9	E	E	707.3E	708.2	E	754.1	E	771.0	785.1	788.2			
FOSSIL DOME WAPELLA 12-27-14-1	31-12-27-14-01-2	601.6	611.0	E	E	E	707.0E	E	760.7	E	767.2	784.0	786.0			
FOSSIL DOME WAPELLA 13-27-14-1	01-13-27-14-01-2	600.4	607.2	E	E	E	704.9E	E	755.6	E	765.0	781.0	782.8			
FOSSIL DOME WAPELLA 14-27-14-1	01-14-27-14-01-2	602.0	607.0	E	E	E	703.0E	E	753.3	E	761.5	779.3	780.6			705.0-723.0
FOSSIL DOME WAPELLA 15-27-14-1	31-15-27-14-01-2	598.8	600.0	E	E	E	701.2E	E	755.1	E	758.0	775.8	777.3			
STURGEON MERLAND WAPELLA 16-27-14-1	01-16-27-14-01-2	597.1	605.0	E	E	702.3E	704.1	E	763.7	E	760.0					703.8-715.1, 740.6-750.6
FOSSIL DOME WAPELLA 16A-27-14-1	02-16-27-14-01-2	596.8	605.6	E	E	E	705.2E	E	767.0	E	762.3	777.6	787.5			
FOSSIL ET AL WAPELLA 5-28-14-1	21-05-28-14-01-2	602.9	612.2	E	698.5	703.2	706.2E	E	767.6	E	766.0	786.0	788.0			
FOSSIL ET AL WAPELLA 6-28-14-1	21-06-28-14-01-2	602.1	613.2	E	E	E	709.0E	E	746.0	E	768.3	788.0	790.2			
FOSSIL ET AL WAPELLA 6A-28-14-1	41-06-28-14-01-2	603.3	613.7	E	702.7E	703.7	706.5									
FOSSIL ET AL WAPELLA 9-28-14-1	01-09-28-14-01-2	601.2	614.5	E	E	E	708.4E	E	759.0	E	780.0	784.3	786.0			721.0-759.0
FOSSIL DOME WAPELLA 10-28-14-1	11-10-28-14-01-2	603.3	616.2	E	E	E	708.7E	E	752.6	E	767.3	786.2	789.5			
ENCOR WAPELLA 11-28-14-1	31-11-28-14-01-2	601.6	600.1	E	E	E	706.0E	E	760.7	E	764.5					
ENCOR ET AL WAPELLA 12-28-14-1	41-12-28-14-01-2	602.4	612.5	E	E	E	703.9E	E	744.9	E	766.3					
TOM JORDAN WAPELLA 13-28-14-1	01-13-28-14-01-2	601.1	600.7	E	699.3E	700.4	702.6	735.0	742.8	E	765.4					
ENCOR WAPELLA 13A-28-14-1	11-13-28-14-01-2	602.5	607.0	E	E	701.5E	732.2	742.5	744.0	E	767.3					
ENCOR WAPELLA 14-28-14-1	41-14-28-14-01-2	601.1	600.5	E	E	E	700.4E	733.0	740.0	E	765.1					
FOSSIL ET AL WAPELLA 15-28-14-1	01-15-28-14-01-2	601.6	611.0	E	E	E	701.0E	735.0	761.0	E	764.0	782.5	786.7			
FOSSIL DOME ET AL WAPELLA 16-28-14-1	31-16-28-14-01-2	600.3	611.0	E	E	E	705.0E	733.4	739.8	E	763.2	781.0	785.0			
ENCOR WAPELLA 1-32-14-1	41-01-32-14-01-2	601.1	609.0	E	E	E	710.4E	730.5	743.0	E	767.2					
RICH WES ET AL WAPELLA 2-32-14-1	11-02-32-14-01-2	602.3	613.9	E	E	E	710.5E	741.3	748.0	E	772.4					
OAK LAWRENCE NUMAC WAPELLA 5-32-14-1	01-05-32-14-01-2	601.1	612.0	687.9	699.2	704.4	707.4	740.1	749.5	E	770.5					
TIDE WATER WAPELLA CROWN NO 10-32	01-10-32-14-01-2	602.3	615.4	672.6	695.2	701.6	706.4	734.9	743.1	E	768.1					
ABERFORD ET AL WAPELLA 1-33-14-1	41-01-33-14-01-2	601.7	606.3	E	E	E	707.4E	732.6	738.2	E	761.0					
ENCOR ET AL WAPELLA 2-33-14-1	31-02-33-14-01-2	601.2	607.8	E	E	E	702.0E	733.0	737.6	E	761.6					
ABERFORD WAPELLA 3-33-14-1	31-03-33-14-01-2	602.4	606.2	E	E	E	703.4E	736.0	741.6	E	764.0					
ENCOR WAPELLA 4-33-14-1	41-04-33-14-01-2	603.1	609.5	E	E	E	705.0E	736.3	741.8	E	766.2					
TIDEWATER WAPELLA NO 5-33	01-05-33-14-01-2	601.0	610.2	E	E	E	706.7E	735.5	742.2	E	765.7					
ENCOR ET AL WAPELLA 5A-33-14-1	11-05-33-14-01-2	602.1	609.0	E	E	E	701.1E	734.6	740.2	E	765.2					
TIDEWATER WAPELLA NO 6-33	01-06-33-14-01-2	601.4	605.6	E	E	E	699.0E	731.5	737.0	750.6	760.5	775.4	780.3	819.0	825.9	700.2-760.8
TIDEWATER WAPELLA NO 7-33	01-07-33-14-01-2	600.0	614.2	E	E	E	709.0E	736.4	742.8	E	760.4					700.0-759.3
TIDE WATER WAPELLA 8-33	01-08-33-14-01-2	599.5	600.2	E	E	E	704.7E	730.3	736.1	E	757.6	773.0	776.6			700.7-756.8
ABERFORD ET AL WAPELLA 8A-33-14-1	41-08-33-14-01-2	600.0	604.6	E	E	E	705.4E	731.1	736.5	E	759.2					
REC WAPELLA CO. 9-33-14-1	01-09-33-14-01-2	598.3	601.4	E	E	E	701.3E	728.5	735.2	E	757.1					
TIDEWATER WAPELLA 10-33	01-10-33-14-01-2	598.6	607.2	E	E	695.4E	697.4	730.0	736.4							742.2-752.6
TIDEWATER WAPELLA 11-33	01-11-33-14-01-2	601.1	610.5	E	695.7E	698.0	701.0	730.9	737.6	E	762.0					657.0-700.0
ENCOR WAPELLA 11A-33-14-1	41-11-33-14-01-2	599.6	606.0	E	690.3E	696.0	699.7	730.4	737.0	E	760.0					
ENCOR WAPELLA 12-33-14-1	41-12-33-14-01-2	602.7	606.9	665.1	692.2	698.0	701.0	733.5	740.0	E	764.0					
ENCOR WAPELLA 14-33-14-1	11-14-33-14-01-2	601.6	609.2	664.4	689.0	694.3	697.7	730.0	735.9	E	761.0					
TIDEWATER WAPELLA 15-33-14-1	01-15-33-14-01-2	597.6	607.5	660.5	685.1	689.5	692.0	726.6	733.9	E	756.5					
TIDE WATER WAPELLA NO 16-33-14-1	01-16-33-14-01-2	598.0	602.3	670.0	681.0	688.5	691.3	725.4	731.8	755.9	756.5	E	772.1			670.6-691.0, 758.5-768.6
ABERFORD ET AL WAPELLA 1-34-14-1	01-01-34-14-01-2	598.2	604.0	E	E	E	699.7E	E	750.0	E	755.0	773.0	775.5			765.5-781.5
ABERFORD ET AL WAPELLA 2-34-14-1	01-02-34-14-01-2	597.9	605.2	E	E	E	705.5E	E	749.5	E	758.2	774.3	776.7			
ABERFORD WAPELLA 3-34-14-1	01-03-34-14-01-2	597.5	600.0	E	E	E	703.0E	E	749.0	E	756.0					

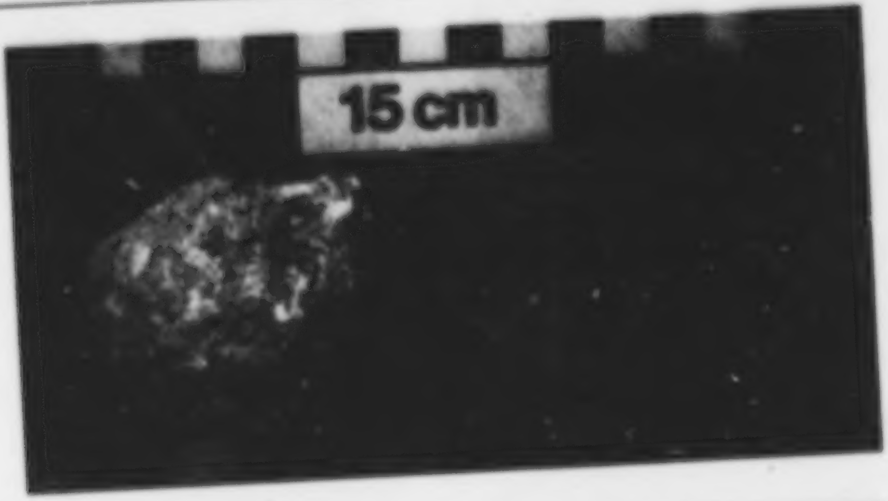
WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	RIERDON FORMATION	RED JACKET FORMATION						LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
					BURROWS MEMBER		MOOSOMIN MEMBER	ROCANVILLE MEMBER								
					BURROWS "B"	BURROWS "A"		ROCANVILLE "C"	ROCANVILLE "B"	ROCANVILLE "A"						
REC WAPELLA SWDW 6-34-16-1	31-06-34-16-01-2	606.1	612.6	E	E	E	709.4E	737.0	742.5	E	765.0					
ABERFORD WAPELLA 6A-34-16-1	41-06-34-16-01-2	601.9	609.5	E	E	E	705.7E	E	748.6	E	759.5	779.5	781.0			
ABERFORD WAPELLA 5-34	41-05-34-16-01-2	599.0	603.6	E	E	E	700.7E	E	732.5	E	756.2	775.0	775.8			
REC WAPELLA CR. 6-34-16-1	01-06-34-16-01-2	597.6	606.7	E	E	E	698.6E	E	744.0	E	757.1					
TIDE WATER WAPELLA NO 7-34	01-07-34-16-01-2	596.5	603.5	E	E	E	696.5E	E	747.4	E	756.5					
TIDE WATER WAPELLA CROWN NO 8-34	01-08-34-16-01-2	596.5	605.9	E	E	E	701.0E	E	741.3	E	754.6					
ABERFORD WAPELLA 8A-34-16-1	21-08-34-16-01-2	596.0	606.1	E	E	E	697.0E	E	745.0	E	754.5					
SOHIO WAPELLA NO 9-34	01-09-34-16-01-2	596.7	600.2	E	E	E	698.9E	E	744.0							708.6-711.1, 736.0-737.0
SOHIO-WAPELLA NO. 10-34	01-10-34-16-01-2	596.2	600.5													
SOHIO WAPELLA NO. 10-34T	02-10-34-16-01-2	596.8	600.4	E	E	E	702.4E	E	736.7	E	752.0					737.6-748.6
TIDE WATER WAPELLA NO 11-34-16-1	01-11-34-16-01-2	595.6	597.7	E	E	E	695.2E	E	730.3	E	755.5					694.9-710.0, 746.9-756.7
TIDE WATER WAPELLA NO 12-34-16-1	01-12-34-16-01-2	598.0	600.2	E	E	E	698.3E									
TIDEWATER WAPELLA CROWN NO 12-34 Y	11-12-34-16-01-2	599.5	601.7	E	E	E	702.3E	727.6	733.3	E	757.6	E	774.5	E	895.0	
ABERFORD WAPELLA 12A-34-16-1	41-12-34-16-01-2	597.7	598.8	E	E	E	700.1E	724.7	730.0	E	755.0					709.8-727.6
TIDE WATER WAPELLA NO 13-34-16-1	01-13-34-16-01-2	596.1	597.4	678.2	680.9	687.0	690.1	720.5	728.5	E	750.6					672.1-680.7
TIDE WATER WAPELLA CROWN NO 14-34	01-14-34-16-01-2	596.8	600.5	674.8	682.7	689.2	692.2	718.7	726.3	E	748.3	767.8	770.0			667.5-685.0
ABERFORD WAPELLA 14A-34-16-1	41-14-34-16-01-2	599.0	600.6	675.6	684.7	690.5	694.0	722.0	727.7	E	750.0	769.5	772.0			709.0-710.0
SOHIO WAPELLA NO 15-34	01-15-34-16-01-2	596.5	606.2	670.6	682.4	688.5	691.6	E	723.8							671.2-676.7, 681.9-688.9 705.6-708.7, 738.3-746.5
SOHIO WAPELLA NO 16-34	01-16-34-16-01-2	595.1	613.3	667.2	687.3	694.9	698.0	E	737.3	E	763.8					685.4-706.5, 728.0-737.3
ENCOR ET AL WAPELLA 16A-34-16-1	21-16-34-16-01-2	595.1	611.4	670.0	690.2	696.3	700.0	E	739.0	E	757.7					
SASKOIL WAPELLA 1-35-16-1	01-01-35-16-01-2	598.0	605.3	E	E	E	702.4E	730.5	733.9							720.9-743.7
CNW WAPELLA 2-35-16-1	01-02-35-16-01-2	595.5	604.0	E	E	E	695.5E	723.0	730.0	E	752.0	E	770.0			
CNW WAPELLA 3-35-16-1	01-03-35-16-01-2	595.5	599.7	E	E	E	696.4E	727.7	733.0	E	750.0	E	772.5			
CNW WAPELLA 4-35-16-1	01-04-35-16-01-2	596.0	606.9	E	E	E	706.0E	E	738.0	E	759.6	E	776.5			
SASKOIL WAPELLA 5-35-16-1	01-05-35-16-01-2	596.2	607.5	E	E	E	696.8E	E	751.9	E	750.9					758.7-761.0
CNW WAPELLA 6-35-16-1	31-06-35-16-01-2	595.0	609.7	E	E	E	700.1E	720.3	735.0	E	759.1	E	779.6			
SASKOIL WAPELLA 7-35-16-1	01-07-35-16-01-2	594.1	602.0	E	E	E	701.3E	724.2	731.8	E	755.9					701.0-719.5
CNW WAPELLA 8-35-16-1	01-08-35-16-01-2	595.7	597.0	E	E	E	697.1E	722.0	730.0	E	771.9	E	781.6			
CNW WAPELLA 9-35-16-1	01-09-35-16-01-2	593.2	602.1	675.0	680.0	686.1	689.9	717.1	725.6	E	776.3	E	779.3			
CNW WAPELLA 10-35-16-1	11-10-35-16-01-2	593.1	604.0	671.0	682.0	688.0	692.0	719.0	727.6	E	774.0	E	780.0			
CNW WAPELLA 11-35-16-1	01-11-35-16-01-2	595.0	607.9	E	685.7E	687.0	690.3	E	755.0	E	783.0	E	787.5			
SASKOIL WAPELLA SWD 12-35-16-1	01-12-35-16-01-2	595.6	607.8	E	E	E	698.3E	E	740.1	E	759.6					
CNW WAPELLA 13-35-16-1	01-13-35-16-01-2	595.3	611.0	662.0	680.0	686.6	690.3	E	760.0	E	771.0	E	777.0			
CNW WAPELLA 14-35-16-1	01-14-35-16-01-2	595.0	611.5	662.5	685.0	689.7	695.3	E	767.6	E	752.2	E	771.0	E	885.0	
PALMER WAPELLA NO 15-35	01-15-35-16-01-2	594.0	601.7	659.0	677.6	686.6	687.6	719.0	727.3							
SASKOIL WAPELLA 15A-35-16-1	02-15-35-16-01-2	592.5	601.7	658.7	677.9	686.3	687.6	719.3	726.6							710.8-719.9
CNW WAPELLA 16-35-16-1	01-16-35-16-01-2	595.1	607.1	660.9	677.1	686.0	687.7	718.0	726.7	E	767.0	E	764.0			
TIDE WATER EARLSWOOD CROWN NO 1-36	01-01-36-16-01-2	596.1	596.5	E	E	E	699.8E	722.1	724.2	760.2	760.8	E	765.0			689.3-704.6
RICH WIS ET AL WAPELLA 3-36-16-1	01-03-36-16-01-2	591.6	594.7	E	E	E	698.3E	716.9	722.6	E	746.2					
DEVON PALMER WAPELLA NO 4-36	01-04-36-16-01-2	597.4	605.0	E	E	E	704.7E	730.6	735.8							
RICH WIS ET AL WAPELLA 5-36-16-1	01-05-36-16-01-2	591.0	597.4	E	E	E	697.7E	E	750.6	E	747.7	E	767.8			
CPL-CLARK CAN-WAPELLA 6-36-16-1	01-06-36-16-01-2	595.8	601.4	E	E	E	698.7E	725.0	730.0	E	754.6					
RICH WIS ET AL WAPELLA 7-36-16-1	01-07-36-16-01-2	592.2	595.3	E	E	E	696.5E	722.1	729.1	E	752.7	E	766.3			
BAKKE WAPELLA 11-36-16-1	01-11-36-16-01-2	596.8	604.1	662.6	681.5	687.9	691.9	721.0	730.3	E	751.9					
RICH WIS ET AL WAPELLA 12-36-16-1	01-12-36-16-01-2	596.2	605.6	E	685.8E	689.2	692.5	730.3	734.0							
CROMER VALLEY WAPELLA 12A-36-16-1	21-12-36-16-01-2	592.5	595.5	E	E	E	696.0E	714.0	720.0	E	762.3					
CNW WAPELLA 13-36-16-1	01-13-36-16-01-2	593.2	600.0	666.5	677.0	683.0	687.0	E	727.3	E	760.0	E	766.7			

WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	PIERSON FORMATION	RED JACKET FORMATION						LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
					BURROWS BURROWS "B"	MEMBER BURROWS "A"	MOOSOMIN MEMBER	ROCANVILLE ROCANVILLE "C"	MEMBER ROCANVILLE "B"	ROCANVILLE "A"						
MARATHON WAPELLA 14-36-14-1	01-14-36-14-01-2	595.1	597.4	655.6	675.1	680.9	684.6	716.0	724.5	E	749.2	E	763.0			
CNW WAPELLA 6-1-15-1	01-06-01-15-01-2	598.0	599.0	657.6	680.0	686.7	690.0	720.0	722.5	E	750.0	E	768.3			
CNW WAPELLA 13-1-15-1	01-13-01-15-01-2	596.0	595.4	657.0	677.0	683.0	686.9	714.8	719.8	E	744.7	E	759.0	E	797.3	
CNW WAPELA 1-2-15-1	01-01-02-15-01-2	595.6	597.8	656.0	675.5	682.0	685.2	717.0	721.7	E	746.0	E	766.0			
TIDEWATER WAPELLA CR 2-2-15-1	01-02-02-15-01-2	591.9	600.5	654.7	679.7	685.8	688.0	E	736.4	E	749.8					709.3-721.5
CNW WAPELLA 3-2-15-1	01-03-02-15-01-2	595.9	600.5	654.0	675.6	682.2	685.0	E	743.0	E	749.9	E	763.8			
CNW WAPELLA 4-2-15-1	01-04-02-15-01-2	595.3	600.7	658.0	678.1	685.0	688.5	E	738.0	E	748.1	E	759.6			703.0-721.0
CNW WAPELLA 5-2-15-1	01-05-02-15-01-2	595.1	601.5	656.2	677.2	684.0	687.6	E	728.4	E	751.0	E	763.0	E	800.6	
CNW WAPELLA 6-2-15-1	01-06-02-15-01-2	595.5	601.0	655.3	677.6	684.4	687.8	E	744.2	E	752.0	E	764.2			729.0-738.0, 759.0-767.0
CNW WAPELLA 7-2-15-1	21-07-02-15-01-2	595.2	600.6	655.7	679.4	685.6	689.5	E	733.0	E	767.0	E	765.1			704.0-721.0
CNW WAPELLA 8-2-15-1	21-08-02-15-01-2	594.4	598.0	653.9	676.6	682.6	686.0	E	727.0	E	765.8	E	759.0			
CNW WAPELLA 11-2-15-1	01-11-02-15-01-2	594.8	600.2	657.2	679.6	685.5	689.0	723.0	727.5	E	751.0	E	763.5			
CNW WAPELLA 12-2-15-1	01-12-02-15-01-2	594.4	598.8	652.9	678.0	684.9	688.2	714.0	727.3	E	751.1	E	762.0			
CNW ET AL WAPELLA 13-2-15-1	01-13-02-15-01-2	595.5	598.1	652.0	676.3	682.4	686.0	715.0	725.0	E	748.9	E	760.8			
CNW WAPELLA 14-2-15-1	01-14-02-15-01-2	589.7	595.0	650.1	672.3	678.0	687.6	714.0	719.8	E	746.0	E	757.0			710.0-757.0
ABERFORD WAPELLA 1-3-15-1	41-01-03-15-01-2	595.9	602.8	657.1	678.0	685.0	688.5	720.0	727.8	E	749.6	E	763.0			
IMPERIAL WAPELLA NORTH 2-3J-15-1	01-02-03-15-01-2	595.8	600.8	655.3	679.7	686.4	689.8	719.3	728.5	E	753.8					699.6-709.3, 701.3-709.3
ABERFORD WAPELLA 2A-3-15-1	21-02-03-15-01-2	595.1	602.4	660.2	682.9	689.0	692.6	724.0	731.7	E	753.3					
TIDEWATER WAPELLA NO 3-3	01-03-03-15-01-2	596.2	598.9	659.0	681.2	687.6	690.7	721.0	729.1	E	760.5					706.1-709.6, 731.5-746.8
TIDEWATER WAPELLA NO 4-3	01-04-03-15-01-2	594.1	601.1	657.2	679.7	685.2	688.2	716.0	727.9	E	749.8	E	788.1	E	807.1	660.0-686.4, 705.5-731.5
TIDEWATER WAPELLA NO 5-3	01-05-03-15-01-2	595.6	604.4	658.1	679.7	686.1	688.8	721.5	729.4	E	751.3					
TIDEWATER WAPELLA 6-3-15-1	01-06-03-15-01-2	594.1	601.4	652.5	680.9	686.7	690.1	721.5	729.4	E	760.2					
ABERFORD WAPELLA 6A-3-15-1	31-06-03-15-01-2	595.4	602.3	658.0	680.1	685.7	689.0	720.0	720.6	E	767.0					
ABERFORD WAPELLA 7-3-15-1	01-07-03-15-01-2	595.4	598.3	655.0	675.7	681.0	684.6	720.8	723.1	E	758.0	E	787.6			
ABERFORD WAPELLA 8-3-15-1	41-08-03-15-01-2	594.1	601.7	656.6	679.0	685.7	689.2	E	725.0	E	767.0	E	786.6			
ABERFORD WAPELLA 9-3-15-1	41-09-03-15-01-2	595.6	597.8	653.5	677.3	683.9	687.0	710.9	726.0	E	760.9	E	768.0			
ENCOR WAPELLA 10-3-15-1	11-10-03-15-01-2	595.9	597.6	656.2	677.1	684.0	687.1	710.8	727.0	E	750.0	E	768.6			
COLGAS DOME WAPELLA 12-3-15-1	21-12-03-15-01-2	594.7	604.8	657.2	681.1	685.7	688.9	720.0	727.8	E	754.2					
TIDE WATER WAPELLA CROWN NO 1-6-15-1	01-01-06-15-01-2	595.0	604.1	656.8	676.0	682.7	685.0	E	733.3	E	755.5					
TIDE WATER-WAPELLA CROWN NO. 2-6	01-02-06-15-01-2	596.8	607.5	670.3	682.7	690.1	693.1	E	737.0	E	755.9	E	772.1			
ENCOR ET AL WAPELLA 3-6-15-1	11-03-06-15-01-2	598.3	608.2	667.3	686.6	691.2	694.3	E	739.4	E	757.8	E	773.0			
ABERFORD WAPELLA 5-6-15-1	41-05-06-15-01-2	599.6	606.1	662.8	685.8	692.6	696.0	727.7	734.7	E	759.5	E	774.9		880.0	
ABERFORD WAPELLA 6-6-15-1	01-06-06-15-01-2	600.5	609.5	662.0	685.7	692.0	695.3	728.0	734.0	E	759.2	E	776.0			
HBC WAPELLA CR 7-6-15-1	01-07-06-15-01-2	597.7	607.2	659.6	687.5	687.6	691.0	726.5	728.4	E	755.9					
TIDE WATER WAPELLA CROWN NO 8-6	01-08-06-15-01-2	595.0	606.9	659.3	681.5	688.2	691.3	722.4	728.4	E	753.8	E	769.6			
ENCOR ET AL WAPELLA 10-6-15-1	31-10-06-15-01-2	598.1	605.5	657.8	679.1	686.9	688.0	721.4	730.0	E	756.0	E	778.5			
CO-OP DOME ET AL WAPELLA 7-5-15-1	01-07-05-15-01-2	599.8	607.2	663.2	687.9	694.6	697.7	730.3	738.2	E	760.5	E	776.6			
TIDEWATER WAPELLA CR 5-6-15-1	01-05-06-15-01-2	599.2	606.2	679.4	691.9	698.0	700.7	E	742.0	E	778.0	E	786.9			
CNW WAPELLA 2-9-15-1	01-02-09-15-01-2	596.6	608.9	660.4	681.0	688.0	691.3	725.1	731.0	E	757.8	E	773.0	E	805.2	
CNW WAPELLA 11-9-15-1	11-11-09-15-01-2	597.7	605.0	657.1	676.7	682.4	686.0	710.7	726.0	E	751.7	E	785.0	E	806.6	
NORTHERN PETE TU WAPELLA 2-10-15-1	01-02-10-15-01-2	592.8	597.1	652.3	674.2	681.2	684.6	710.7	725.4	E	747.4					
CNW WAPELLA 3-10-15-1	31-03-10-15-01-2	594.3	598.5	652.6	674.5	680.9	684.0	715.8	722.2	E	740.8	E	780.5	E	807.0	
CNW WAPELLA 6-10-15-1	01-06-10-15-01-2	595.3	597.4	653.6	674.3	681.0	684.4	715.1	722.0	E	752.1	E	781.6			727.0-743.0
CNW WAPELLA 12-10-15-1	01-12-10-15-01-2	595.7	600.0	654.0	675.7	682.0	685.3	715.0	725.1	E	748.0	E	781.6			
CNW WAPELLA 2-11-15-1	41-02-11-15-01-2	594.3	594.4	650.8	674.0	680.1	683.8	720.5	725.4	E	748.0	E	757.6		792.0	
ADLO NORTH WAPELLA 6-11-15-1	01-06-11-15-01-2	592.5	594.1	653.5	673.3	679.7	685.4	718.1	722.4	E	745.2	E	755.9			680.7-701.0
CNW WAPELLA 7-11-15-1	01-07-11-15-01-2	595.3	592.8	647.2	670.6	670.6	679.9	E	727.4	E	745.2	E	755.0			
CNW WAPELLA 8-11-15-1	01-08-11-15-01-2	595.0	588.0	642.1	665.0	671.0	674.5	E	736.4	E	742.0	E	752.0	E	789.0	

WELL NAME	WELL LOCATION	K.B.	MASEFIELD FORMATION	RIERDON FORMATION	RED JACKET FORMATION						LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
					BURROWS MEMBER		MOOSOMIN MEMBER	ROCANVILLE MEMBER								
					BURROWS "B"	BURROWS "A"		ROCANVILLE "C"	ROCANVILLE "B"	ROCANVILLE "A"						
CNW ET AL WAPELLA 11-12-15-1	11-11-12-15-01-2	596.6	591.8	650.0	669.6	676.0	679.5	706.0	710.0	E	741.5	E	758.5			
CNW ET AL WAPELLA 13-12-15-1	21-13-12-15-01-2	595.5	592.5	645.0	670.0	676.0	679.2	E	709.0	E	741.5					
SOHIO NORTH WAPELLA KD 2-13	01-02-13-15-01-2	592.5	586.7	650.1	661.1	668.6	671.5	699.3	706.4	E	739.7	E	757.6	E	780.0	
HOME NORTH WAPELLA 9-13-15-1	01-09-13-15-01-2	591.3	585.1	638.6	656.5	663.9	666.9	698.0	702.0	E	736.3					
SOHIO NORTH WAPELLA KD 11-13	01-11-13-15-01-2	596.6	589.5	655.3	658.1	665.1	667.8	E	725.7	E	733.6					662.9-682.1, 691.6-727.9
SASKOIL N WAPELLA 13-13-15-1	01-13-13-15-01-2	595.6	588.3	644.0	675.5	666.2	667.2	E	721.2	E	730.4	E	749.8	E	755.6	682.1-710.0
SASKOIL N WAPELLA 14-13-15-1	41-14-13-15-01-2	595.1	585.5	649.0	655.3	662.6	666.0	E	730.9	E	735.7	E	746.9			
SASKOIL N WAPELLA 15-13-15-1	01-15-13-15-01-2	591.6	585.4	638.3	652.9	659.6	662.6									
HOME NORTH WAPELLA 16-13-15-1	01-16-13-15-01-2	592.2	585.2	637.6	656.5	664.2	666.9	697.6	704.7	E	731.2	E	744.0			
KPL-CLARK CNW WAPELLA 9-14-15-1	01-09-14-15-01-2	595.7	587.7	638.3	658.7	666.5	667.5	E	712.9	E	741.9					
TW NORTH WAPELLA CR 16-14-15-1	01-16-14-15-01-2	593.6	586.7	636.1	657.6	665.5	666.9	E	711.6	E	734.9	E	740.5			
SASKOIL NORTH WAPELLA 16A-14-15-1	02-16-14-15-01-2	596.3	588.7	637.6	659.5	665.6	668.5	E	713.0	E	736.2	E	748.5			675.5-691.5
CNW PCP WAPELLA 7-17-15-1	21-07-17-15-01-2	595.6	590.0	645.0	665.1	669.3	672.7	E	715.0	E	737.0	E	752.0	E	791.0	
CROMER VALLEY 9-17-15-1	11-09-17-15-01-2	595.9	595.5	650.0	669.8	677.0	679.9	E	715.0	E	735.0	E	755.0			
ARCO BURROWS 2-18-15-1	21-02-18-15-01-2	600.5	602.2	661.6	682.1	688.0	691.9	E	740.0	E	756.5	E	769.6			
CNW ET AL WAPELLA 7-20-15-1	31-07-20-15-01-2	594.1	583.1	640.3	657.1	663.1	666.7	E	716.3	E	733.2	E	749.0			
KPL-CLARK CNW-WAPELLA 9-21-15-1	01-09-21-15-01-2	596.6	591.9	646.2	667.8	673.6	676.7	E	710.2							
TRICENT ET AL WAPELLA 14-21-15-1	11-14-21-15-01-2	596.9	580.0	640.5	658.0	666.5	668.1	E	716.8	E	731.9	E	746.5	E	765.0	
CNW WAPELLA 8-22-15-1	11-08-22-15-01-2	596.7	586.6	643.0	662.1	669.0	672.3	705.0	710.0	E	735.8	E	750.0			
TW NORTH WAPELLA CR 14-22-15-1	01-14-22-15-01-2	595.6	590.1	646.2	665.4	671.6	675.2	E	719.3	E	734.6	E	747.1	E	765.9	657.5-710.5
TIDEX ET AL WAPELLA 2-23-15-1	21-02-23-15-01-2	596.2	588.6	641.5	667.1	670.0	677.1									
SASKOIL WAPELLA 2-26-15-1	21-02-26-15-01-2	591.0	585.2	638.3	656.1	661.7	665.1	E	709.5	E	707.6	E	741.0			671.2-682.5
JORDAN NORTH WAPELLA 6-26-15-1	01-06-26-15-01-2	595.3	588.6	648.3	661.0	668.7	671.8									
PALMER CRYSTAL WAPELLA KD 7-26	01-07-26-15-01-2	591.0	582.5	637.0	652.3	659.6	662.3	E	710.0	E	726.6					665.0-669.6, 676.5-677.6
TENNECO JORDAN WAPELLA 7-29-15-1	01-07-29-15-01-2	596.1	581.9	639.5	656.5	662.6	665.7	E	711.6	E	729.6	E	746.0	E	781.5	
SOHIO NORTH WAPELLA KD 12-36	01-12-36-15-01-2	592.8	576.7	606.0	650.7	658.7	662.0	E	697.7	E	722.6	E	736.6	E	786.6	648.7-678.3
DEVON PALMER BURROWS 13-36-15-1	01-13-36-15-01-2	590.6	579.1	621.0	649.0	656.3	659.5	690.6	695.7	E	700.5	E	720.9	E	789.6	
CONO ET AL BURROWS 12-1-16-1	41-12-01-16-01-2	596.7	580.0	605.0	645.0	651.7	654.6	E	690.0							655.3-666.3
CONO ET AL BURROWS 13-1-16-1	41-13-01-16-01-2	601.1	581.5	606.1	643.7	650.0	653.0	E	699.7	E	720.7	E	730.5	E	760.9	659.0-675.0
SASKOIL EAST BURROWS 15-1-16-1	41-15-01-16-01-2	601.1	586.9	613.2	647.0	653.0	655.6	E	697.0	E	718.9	E	730.0			
B-M-S BURROWS CR 8-6-16-1	01-08-06-16-01-2	597.8	585.5	640.7	656.5	662.6	665.0	696.0	702.3	E	726.6	E	740.6	778.5	781.5	
CONTACT ET AL WAPELLA 1-11-16-1	01-01-11-16-01-2	597.6	581.0	607.0	646.9	653.6	657.0	686.0	689.0	E	711.0	E	729.0			
BEDOWATCH TIDEWATER EAST BURROWS 2-12	01-02-12-16-01-2	602.0	581.6	616.5	645.6	652.0	656.6	E	692.5	E	713.0	E	730.6	E	752.9	
CONO ET AL BURROWS 6-12-16-1	11-06-12-16-01-2	598.6	578.0	602.0	641.2	647.6	650.7									653.0-667.5
TENNECO JORDAN WHITEWOOD 7-12-16-1	01-07-12-16-01-2	598.3	575.0	615.4	641.0	647.1	649.2	E	680.0	E	756.1	E	710.3	E	756.5	
CONO ET AL BURROWS 12-12-16-1	11-12-12-16-01-2	599.2	581.0	636.6	647.6	654.0	656.9									658.0-667.0
DEVON PALMER EAST WHITEWOOD	01-01-16-16-01-2	596.5	565.6	622.7	637.9	644.3	647.6	E	686.6	E	706.0	E	721.0	E	730.2	
HUBER MANN B.A. WHITEWOOD 6-29-16-1	01-06-29-16-01-2	599.3	570.3	617.5	637.3	643.1	645.3									
CALIFORNIA STANDARD BURROWS 2-36	20-02-36-16-01-2	602.0	552.6	596.2	617.8	626.2	628.1	E	671.2	E	687.6	E	708.6	E	706.5	617.8-642.5, 713.2-727.0
CHEVRON NORTH BURROWS 8-36-16-1	01-08-36-16-01-2	602.6	560.0	590.5	607.0	612.1	615.0	E	665.1	E	686.9	E	699.2	E	717.0	617.0-646.0, 7[illegible]-727.0
HUDSON WHITEWOOD 4-6-17-1	21-06-06-17-01-2	597.0	560.5	610.2	621.0	627.9	630.3	E	676.7	E	686.9					
CHEVRON CLAYRIDGE 8-10-17-1	11-08-10-17-01-2	606.7	540.0	575.0	606.6	609.0	611.0	E	667.5	E	711.7	E	E	E	716.9	674.0-688.6
RIDDLE TIDEWATER CLAYRIDGE CR 16-16	01-16-16-17-01-2	605.0	544.2	580.3	613.6	618.7	620.0	E	659.0	E	676.7	E	687.9	E	696.5	
HUDSON WHITEWOOD 5-16-17-1	31-05-16-17-01-2	600.6	551.7	599.0	613.6	618.6	625.6	E	669.3	E	691.6					
HUDSON WHITEWOOD 1-18-17-1	11-01-18-17-01-2	600.2	549.2	E	E	E	650.75	E	702.9	E	713.2					
UNITED TRI-STAR GROVE PK 16-26-17-1	31-16-26-17-01-2	595.3	528.8	576.3	579.0	583.3	585.1	E	631.8	E	660.0	E	666.0	E	669.7	
HUBER MANN B.A. WHITEWOOD 7-28-17-1	01-07-28-17-01-2	601.2	534.3	E	E	E	597.6	E	636.4	E	673.0	E	678.2	E	686.0	
UNITED TRI-STAR GROVE PARK 9-36-17-1	11-09-36-17-01-2	587.7	508.0	557.0	558.5	562.5	566.3	E	602.3	E	637.0	E	E	E	640.0	

WELL NAME	WELL LOCATION	K.B.	MANNVILLE FORMATION	RIERDON FORMATION	RED JACKET FORMATION						LOWER GRAVELBOURG UNIT B	LOWER GRAVELBOURG UNIT A	UPPER WATROUS	LOWER WATROUS	SOURIS VALLEY	CORED JURASSIC
					[illegible]	[illegible] MEMBER	[illegible] MEMBER	[illegible]	[illegible] MEMBER	[illegible]						
[illegible] LANGBANK 2-28-12-2	01-02-28-12-02-2	671.8	738.5	837.3	854.7	859.2	862.6	882.2	885.3	E	923.2	947.3	965.1	995.2	——	
CAN-DEV TW LANGBANK 15-28-12-2	01-15-28-12-02-2	667.2	739.1	827.8	840.6	845.2	848.0	E	887.0	E	908.3	955.4	958.2	981.5	999.0	
AMERADA TENNECO LANGBANK 15A-28-12-2	02-15-28-12-02-2	666.6	737.6	828.4	841.6	845.5	846.6	E	887.0	0	899.5	956.8	958.2	979.6	999.6	
FOSSIL 300 ET AL WAPELLA 6-25-14-2	11-06-25-14-02-2	605.7	612.9	707.8	709.0	715.4	718.3	0	758.9	E	779.0	795.0	802.5	842.6	861.0	
D-W AND LARIO W WAPELLA 2-32-14-2	01-02-32-14-02-2	617.8	602.5	725.6	736.1	741.0	744.0	770.0	777.8	0	799.8	819.0	828.6	845.0	885.3	
TW SOUTH W WAPELLA 16-33-14-2	01-16-33-14-02-2	613.3	604.8	705.0	717.8	725.6	725.7	758.9	760.0	E	786.4	803.1	815.2	851.5	868.7	676.2-778.2
SASKOIL WAPELLA WEST 8-34-14-2	41-08-34-14-02-2	605.4	619.2	686.1	712.0	717.6	720.6	753.0	757.0	0	786.1	797.8	805.6			
CPOG WAPELLA 9-35-14-2	01-09-35-14-02-2	601.4	617.8	680.9	709.0	714.8	717.3	760.8	756.3	E	782.1	776.4	798.6	859.4	867.1	
GREL PIPESTONE 1-36-14-2	31-01-36-14-02-2	600.5	613.6	671.5	704.1	709.9	712.0	E	754.4							
ZD HB WAPELLA 16-8-15-2	01-16-08-15-02-2	600.3	609.0	668.3	705.9	710.0	713.8	760.8	753.4	0	781.5	798.6	801.0	838.2	854.1	
ANADARKO WAPELLA 11-10-15-2	01-11-10-15-02-2	604.7	613.9	686.9	697.7	703.2	705.9	E	755.0	0	768.7					
CO-OP DOME ET AL WAPELLA 1-12-15-2	01-01-12-15-02-2	601.0	605.3	675.1	680.1	696.5	699.2	E	761.3	E	765.7					
DOME HACO WAPELLA HD 16-15	01-16-15-15-02-2	590.2	590.8	661.1	679.4	685.8	688.5	E	733.3	E	757.4	768.4	776.5	814.1	825.0	687.4-688.6
CHEVRON WHITEWOOD 4-18-15-2	21-04-18-15-02-2	618.4	623.6	705.7	716.0	720.8	725.5	E	771.0	E	797.0	807.1	815.0	863.0	869.6	717.0-744.0
B.A. SILVERWOOD HOGARTH 4-20-15-2	01-04-20-15-02-2	610.0	615.4	E	703.20	709.0	712.0	0	748.9	0	774.5	785.5				
KPL-CLARK. CAN-WAPELLA 4-26-15-2	01-04-26-15-02-2	602.3	603.0	661.7	684.5	690.7	693.7	0	739.4							
TRITON TW E WHITEWOOD CR 16-28-15-2	01-16-28-15-02-2	602.7	602.3	672.1	681.2	688.2	691.3	0	730.0	0	754.4	788.1	772.4	807.7	815.3	
LAKE ECHO - WHITEWOOD 11-15-16-2	01-11-15-16-02-2	[illegible]	575.5	E	E	E	665.70	E	697.7	0	728.0	E	758.2			
HADSON WHITEWOOD 16-22-16-2	41-16-22-16-02-2	[illegible]	590.0	E	E	E	668.2	E	680.9	0	766.2					
HADSON WHITEWOOD 1-29-16-2	11-01-29-16-02-2	598.0	577.3	E	E	E	E	E	690.40	0	720.2					
HADSON WHITEWOOD 1-36-16-2	21-01-36-16-02-2	590.1	560.0	E	E	E	636.10	E	677.0	E	695.6					
SASKOIL WHITEWOOD 13-10-17-2	01-13-10-17-02-2	588.6	557.7	E	E	E	E	E	669.10	0	690.0					
HADSON WHITEWOOD 1-12-17-2	11-01-12-17-02-2	595.3	557.2	E	E	E	652.00	0	678.5	E	690.7					
TRITON TW WHITEWOOD CR 5-16-17-2	41-05-16-17-02-2	588.1	556.6	E	E	E	E	E	666.20	E	686.6	0	759.4	721.9		
TRI-STAR ST. LUKE 16-26-17-2	01-16-26-17-02-2	594.2	540.2	E	E	E	648.20	E	660.6	E	681.1	0	642.4	E	656.0	
TRI STAR WHITEWOOD W 8-31-17-2	41-08-31-17-02-2	580.6	533.0	E	E	E	E	648.30	653.1	E	680.7	0	685.1	E	656.2	

Appendix B: Selection of Photographs



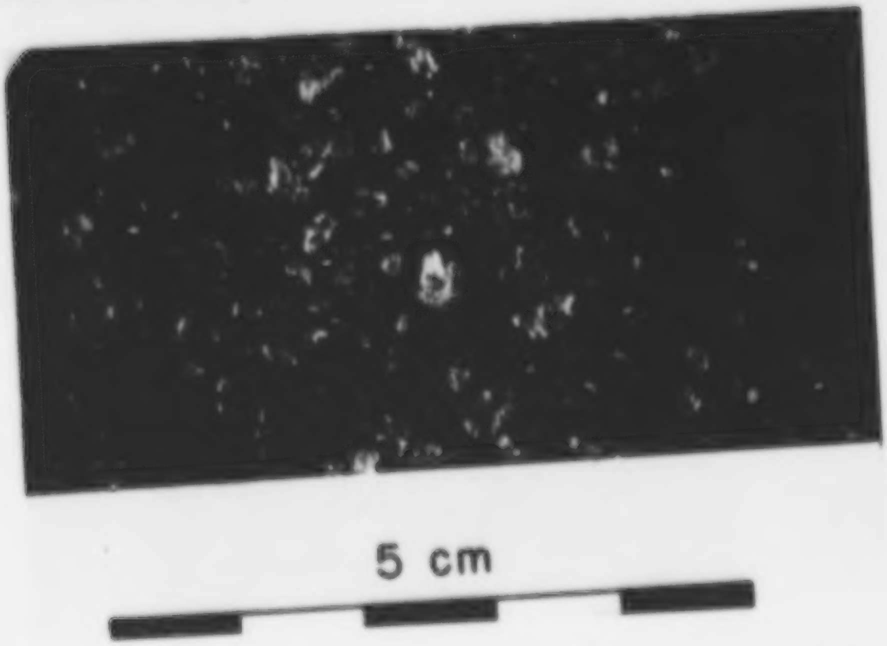
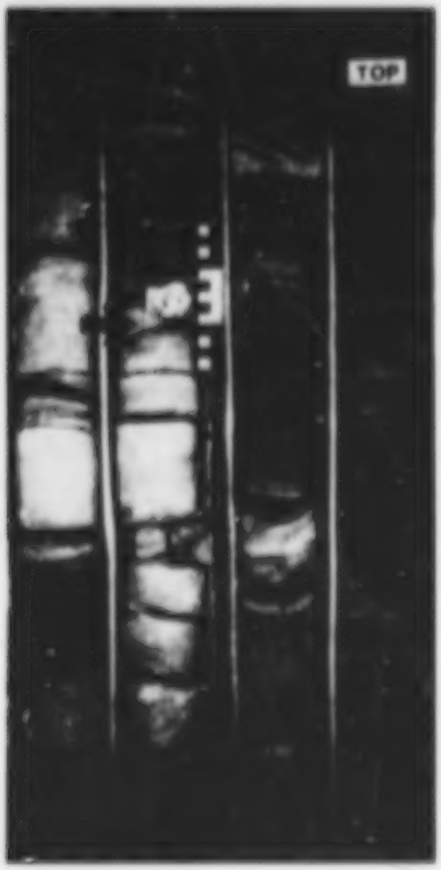


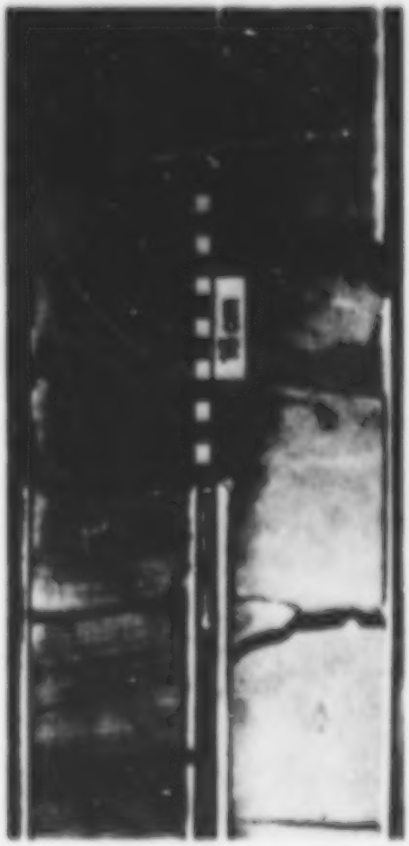
Photo 1. (Top) Unit A of the lower Gravelbourg. Note the vuggy nature of the weathered dolomitic limestone sample on the left and intraclasts of well-rounded chalcedonic chert up to pebble size in the sample on the right. (Imperial Dahinda #1 well (Lsd. 10-23-10-23W2) at 1297.2 m).

Photo 2. (Bottom) "Thin-shelled" pelecypods (*Modiolus* ?). Note the paper-thin nature of the shells in this olive-grey (5Y4/1) calcareous mudstone in unit B of the lower Gravelbourg. (Saskoil Westmin Red Jacket 6-24-14-32 well (Lsd. 6-24-14-32W1) at 703.0 m)

Photo 3. (Left) Oolitic and peloidal bioclastic limestone. Note the high-angle planar cross-stratification (approximately 25°) in the lower half of photo and the small-scale graded bedding in the upper half. Arrow points to reactivation surface. Also note the stylolite in the upper half of photo. (Tricent *et al.* Moosomin 4-28-14-31 well (Lsd. 4-28-14-31W1) at 664.0 m)

Photo 4. (Right) *Gryphaea*-bearing sandstone contains abundant well-worn *Gryphaea nebrascensis* and other pelecypod shell material. (Tricent *et al.* Red Jacket 12-4-14-32 (Lsd. 12-4-14-32W1) at 656.5 m)





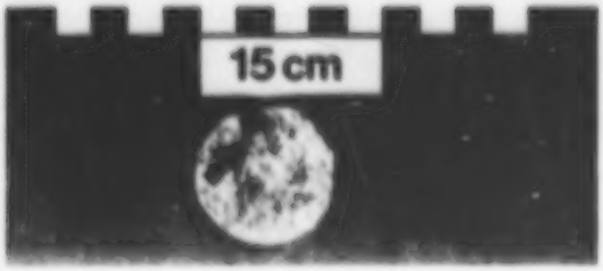


Photo 5. (Left) Rocanville "A"/"B" contact. Arrow indicates sharp and erosive contact at base of high-angle planar cross-stratified sandstone in Rocanville "B". Siltstone pebbles of same composition as underlying Rocanville "A" are incorporated in sandstone immediately above contact. (Pondex Pat Parkman 5-22-10-1 well (Lsd. 5-22-10-1W2) at approximately 965.5-967.0 m)

Photo 6. (Centre) Glauconitic micaceous sandstone. Arrow points to a patch of partially glauconitized micaceous and clayey material. X-ray diffraction identified the clay to be glauconitic illite. (Tide Water Wapella No 16-33-14-1 well (Lsd. 16-33-14-1W2) at approximately 784.7 m)

Photo 7. (Right) Low- and high-angle planar cross-stratification. Arrows point to high-angle (at top, approximately 25°) and low-angle (at bottom, approximately 5 to12°) planar cross-stratification in dolomitic sandstone. This photo is close-up of core in Photo 17. (CNW Wapella 6-2-15-1 well (Lsd. 6-2-15-1W2) at approximately 747.3-747.7 m)

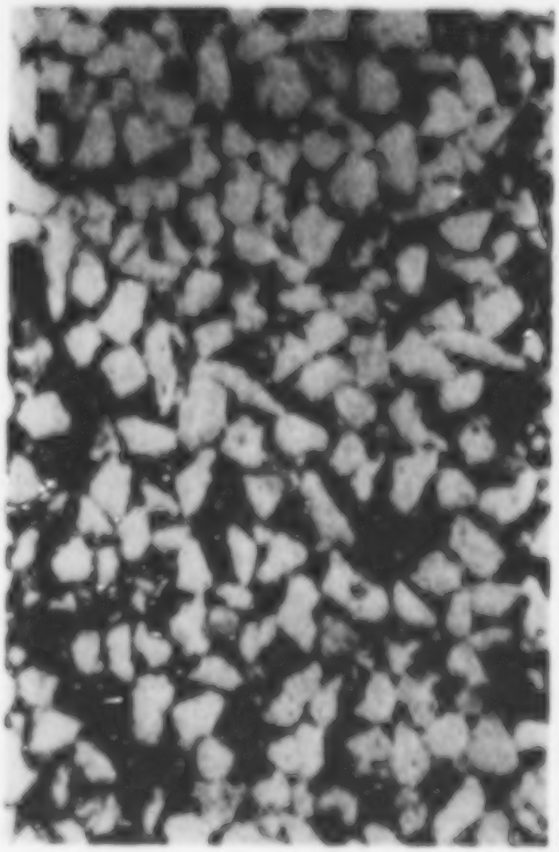
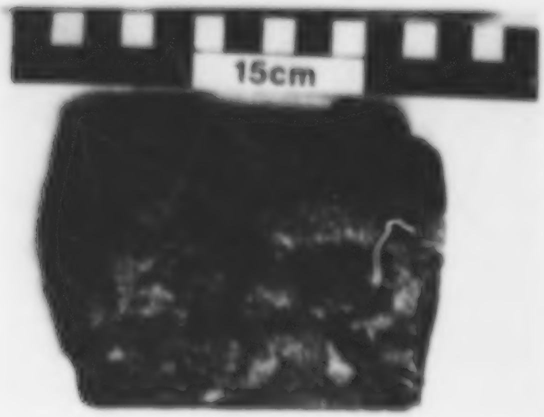


Photo 8. (Left) Glauconitic/chamositic (?) sandstone. Greenish-grey patches (generally rimming the quartz grains) are suspected to be glauconite and light brown patches (mostly light grey) are suspected to be chamosite (?). The quartz grains in this photo are between 0.10 to 0.25 mm across. (CNW Wapella 14-2-15-1 well (Lsd. 14-2-15-1W2) at approximately 722.3 m)

Photo 9. (Right) Glauconitic fecal (?) pellets. Arrow points to a pellet-like mass, approximately 0.8 mm across, which has a glauconitic rim and brownish-coloured (dark grey) possibly chamositic centre. (CNW Wapella 14-2-15-1 well (Lsd. 14-2-15-1W2) at 719.8 m)



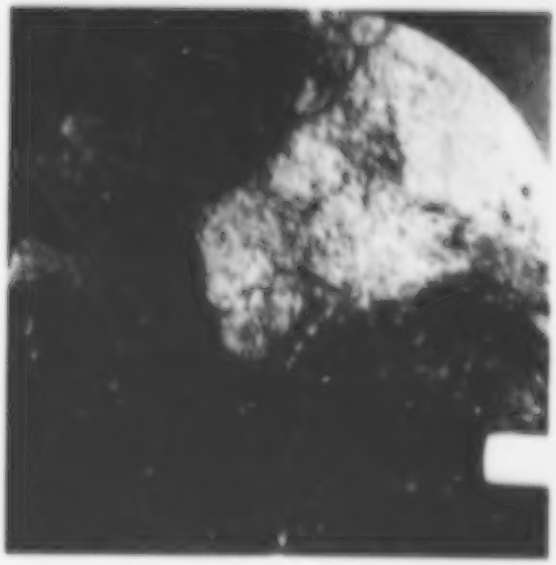


Photo 10. (Upper Left) Variegated dolomitic mudstone. This mudstone is from Rocanville "B" of the Rocanville Member. (Tide Water Wapella No 6-33 well (Lsd. 6-33-14-1W2) at approximately 743.7 m)

Photo 11. (Upper Right) Dessicated mudstone. Profile of mud cracks in variegated mudstone in Rocanville "B" of Rocanville Member. (Tide Water Wapella No 6-33 well (Lsd. 6-33-14-1W2) at approximately 745.2 m)

Photo 12. (Lower Left) Dessicated mudstone. Plan view of mud cracks in Photo 12.

Photo 13. (Lower Right) Rootlet molds (?) in a caliche. (CNW Wapella 14-2-15-1 well (Lsd. 14-2-15-1W2) at approximately 721.5 m)

Photo 14. (Left) Lithographic (micritic) limestone. Arrow points to a sparry calcite infilled pelecypod shell in a sandy (i.e. quartzose) micritic matrix. Scale represents one millimetre. (Saskoil Wapella 14a-35-14-1 well (Lsd. 14a-35-14-1W2) at 719.8 m)

Photo 15. (Right) Coral conglomerate. Arrows point to cross-sectional views of well-worn, cylindrical fragments of the coral *Actinastrea* cf. *A. hyatti* (Wells). Also note fragments of pelecypod shells. (Aberford Wapella 12A-34-14-1 well (Lsd. 12A-34-14-1W2) at 724.5 m)

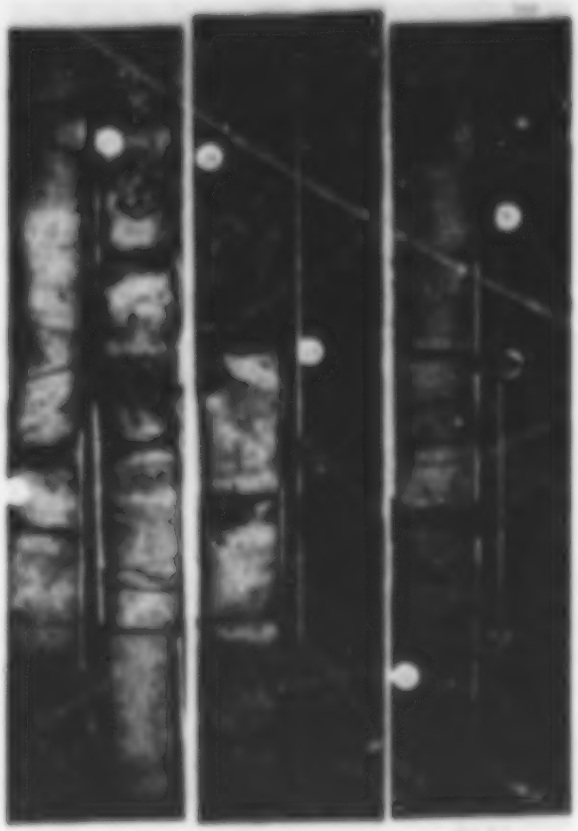
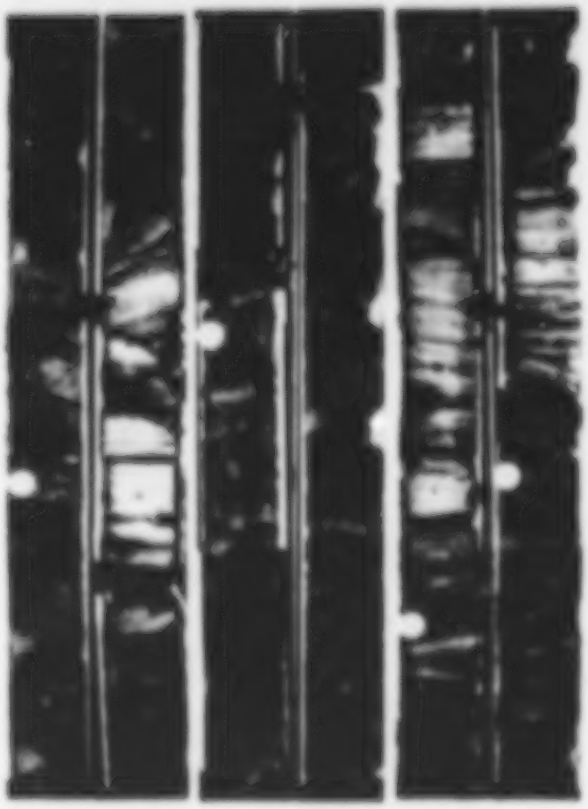


Photo 16. (Left) Rocanville "B"/"C" contact. The overlying sandstone of Rocanville "C" is in sharp and erosive contact with greenish-grey (5GY6/1) mudstone (lighter grey) of Rocanville "B". The greenish-grey mudstone pebbles (arrow) incorporated in the base of the Rocanville "C" are obviously derived from underlying Rocanville "B" mudstone. (CNW Wapella 14-2-15-1 well (Lsd. 14-2-15-1W2) at 720.3 m)

Photo 17. (Right) Rocanville/Moosomin Member contact. Arrow points to the sharp and erosive contact, at approximately 743.9 m, between sandy siltstone of Rocanville "B" and overlying poorly sorted oil-saturated sandstone of Moosomin "A1" of Moosomin "A". Note siltstone pebbles of the same composition as underlying siltstone in Rocanville "B" are incorporated in the base of this sandstone. (CNW Wapella 6-2-15-1 well (Lsd. 6-2-15-1W2) between approximately 743.6-746.0 m)



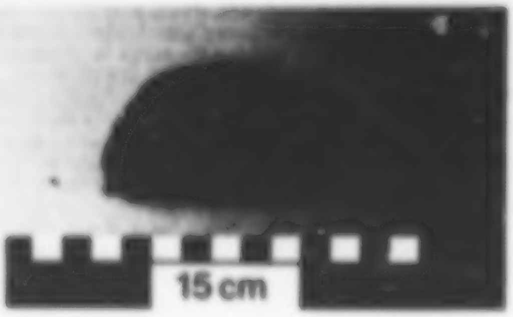


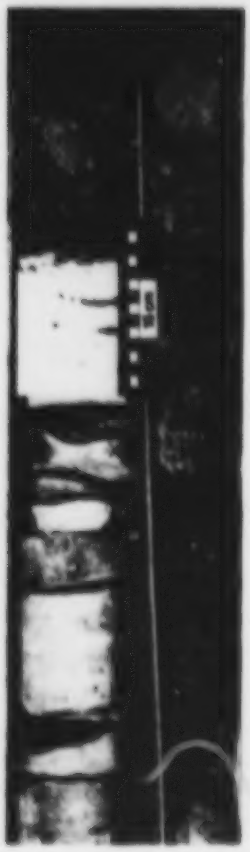
Photo 18. (Upper Left) Massive, low- and high-angle planar cross-stratification. Note that the arrows on the left point to high-angle planar cross-bedding showing opposing flow directions (i.e. bipolar flow). The arrow on the right points to an interval of interlaminated siltstone and argillaceous sandstone. (CNW Wapella 6-2-15-1 well (Lsd. 6-2-15-1W2) between approximately 739.3-743.6 m)

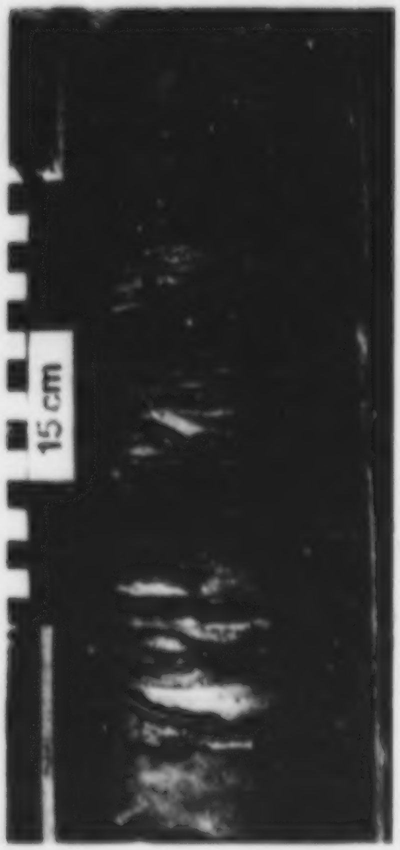
Photo 19. (Bottom Centre) Carbonaceous detritus and mica. (CNW Wapella 6-2-15-1 well (Lsd. 6-2-15-1W2) at 731.2 m)

Photo 20. (Right) Siderite nodule. Arrow points to siderite nodule at base of a poorly sorted sandy and carbonaceous lag deposit in Moosomin "A1" of Moosomin "A". (CDNOXY Red Jacket W 6-25-13-1 well (Lsd. 6-25-13-1W2) at approximately 779.4 m)

Photo 21. (Left) Small-scale wave and current ripples. Upper arrow points to small-scale wave ripple and lower arrow points to a small-scale current ripple in Moosomin "A2" of Moosomin "A". (Aberford Wapella 12A-34-14-1 well (Lsd. 12A-34-14-1W2) at approximately 712.3 m)

Photo 22. (Right) Climbing ripples. The climbing ripples shown here are found in Moosomin "A2" of Moosomin "A". Note pyrite nodule near base. (Arco South Wapella 11-23-14-1 well (Lsd. 11-23-14-1W2) at approximately 737.8 m)





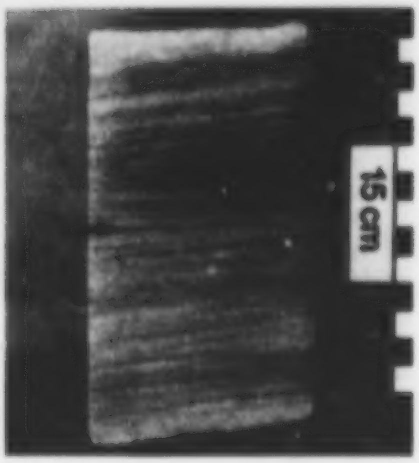


Photo 23. (Left) Moosomin "A"/"B" contact. Arrow points to contact between dolomite-cemented sandstone at top of Moosomin "A" and overlying variegated mudstones in Moosomin "B". (Tide Water Wapella No 6-33 well (Lsd. 6-33-14-1W2) at approximately 720.2 m)

Photo 24. (Centre) Lenticular bedding in Moosomin "B". (Tricent *et al.* Red Jacket 12-4-14-32 well (Lsd. 12-4-14-32W1) at approximately 669.0 m)

Photo 25. (Upper Right) Flaser bedding in Moosomin "B". (Coho *et al.* Welwyn W 8-16-15-31 well (Lsd. 8-16-15-31W1) at approximately 563.4 m)

Photo 26. (Lower Right) "Burrow-mottled" sandstone and mudstone in the Moosomin "B". (Tricent *et al.* Red Jacket 4-4-14-32 well (Lsd. 4-4-14-32W1) at approximately 582.4 m)

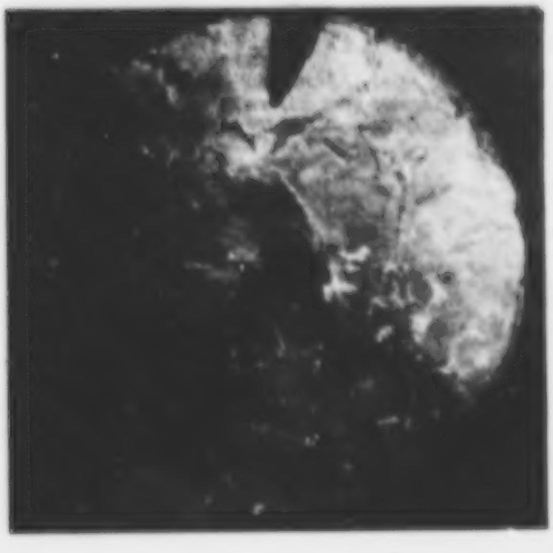


Photo 27. (Upper Left) Low-angle planar cross-stratified sandstone. Arrow points to truncated surface at top of underlying sandstone. in the Burrows "B". (Coho *et al.* Welwyn 1-16-15-31 well (Lsd. 1-16-15-31W1) at approximately 557.8 m)

Photo 28. (Right) Intensely bioturbated sandstone. Bioturbation has completely homogenized this sediment. Arrow points to pyritized pelecypod shell in the Moosomin "B". (CNW Red Jacket 8-5-14-32 well (Lsd. 8-5-14-32W1) at 677.1 m)

Photo 29. (Lower Left) Syneresis cracks. Pen points to syneresis cracks in greenish-grey (5GY6/1) mudstone of Moosomin "B" (Coho *et al.* Welwyn 8-16-15-31 well (Lsd. 8-16-15-31W1) at approximately 560.0 m)

Photo 30. (Left) Algal(?)-laminated sandstone/siltstone. The "pin-striped" appearance is a very distinctive feature of this lithology and is interpreted to be of possible algal origin. Note pyrite nodule near base. (CNW Red Jacket 8-5-14-32 well (Lsd. 8-5-14-32W1) at approximately 680.5 m)

Photo 31. (Right) High-angle planar cross-stratified sandstone. Arrow points to truncated surface at top of cross-bedded sandstone in the Moosomin "B". (Saskoil North Wapella 16A-14-15-1 well (Lsd. 16A-14-15-1W2) at approximately 676.6 m)

Photo 32. (Left) Mudstone drapes. Arrows point to two separate mudstone drapes in a channel sandstone in Moosomin "B". (Saskoil North Wapella 16A-14-15-1 well (Lsd. 16A-14-15-1W2) at approximately 878.6 m)

Photo 33. (Right) Mudstone clasts and pebbles. Mudstone clasts and pebbles are found at base of a moderately consolidated, oil-saturated sandstone which is in sharp contact with a well-cemented sandstone in the Moosomin "B". Scale bar is 5 cm. (Tricent *et al.* Red Jacket 2-4-14-32 well (Lsd. 2-4-14-32W1) at approximately 669.8 m)

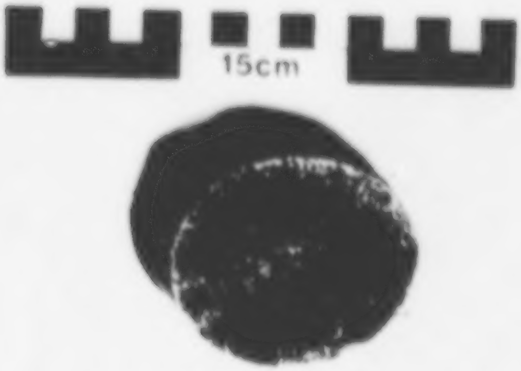
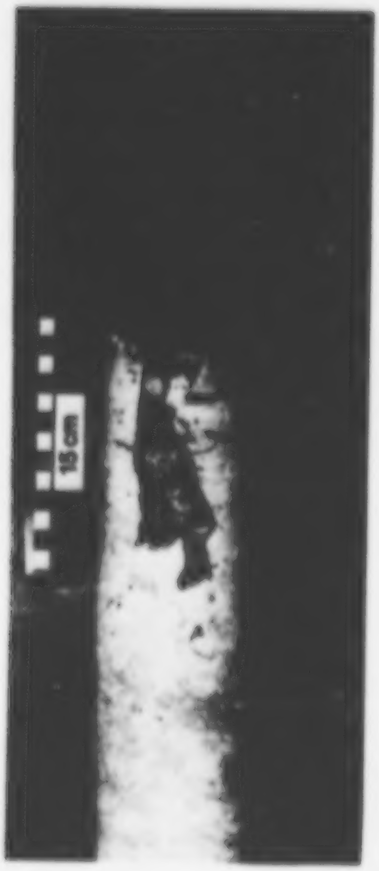


Photo 34. (Upper) "Coffee ground" organic detritus. Oblique view of a high-angle planar cross-stratified, Moosomin "B" sandstone showing laminations largely composed of abundant organic detritus, giving it a so-called "coffee ground" appearance. (Tricent *et al.* Red Jacket 4-4-14-32 well (Lsd. 4-4-14-32W1) at approximately 670.0 m)

Photo 35. (Lower) *Planolites* and *Chondrites* burrows Moosomin "A". The *Chondrites* burrows tend to be round or oval-shaped whereas the *Planolites* burrows tend to be elongated or oval-shaped. (Aberford Wapella 12A-34-14-1 well (Lsd. 12A-34-14-1W2) at approximately 719.0 m)



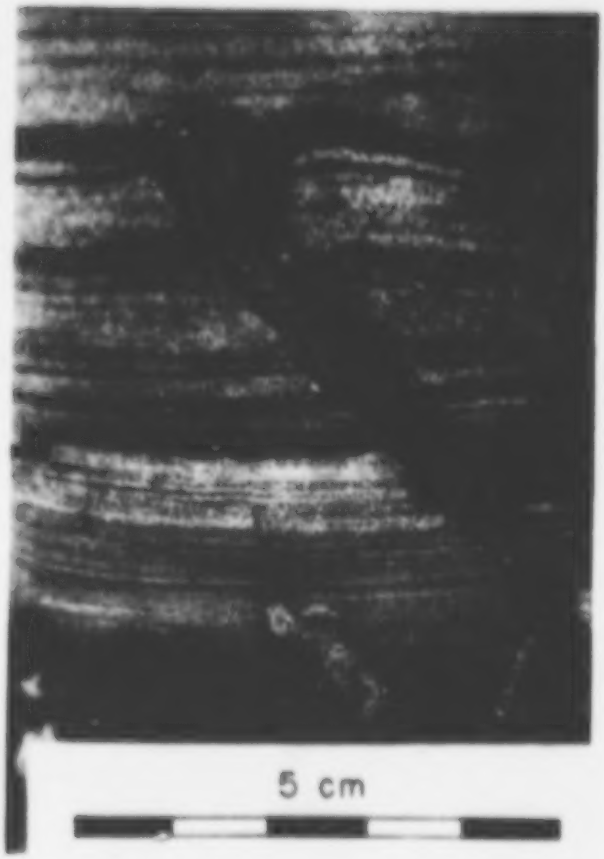


Photo 36. (Left) *Diplocraterion* boring (*Glossifungites* ichnofacies) in the Moosomin "B". (Chevron Whitewood 4-18-15-2 well (Lsd. 4-18-15-2W2) at approximately 723.9 m)

Photo 37. (Right) *Diplocraterion* burrow (*Skolithos* ichnofacies). This burrow in the Moosomin "B" appears to be an escape structure created by its occupant in response to rapid deposition of sand. (Tricent *et al.* Red Jacket 3-15-14-32 well (Lsd. 3-15-14-32W1) at approximately 654.3 m)

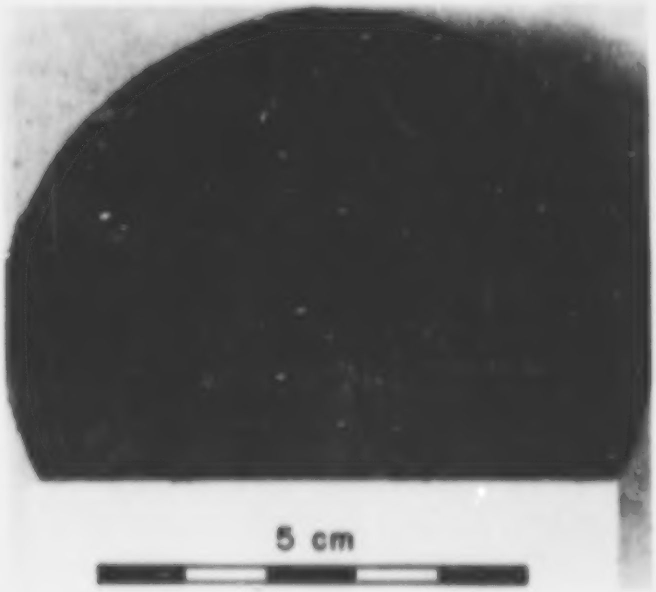
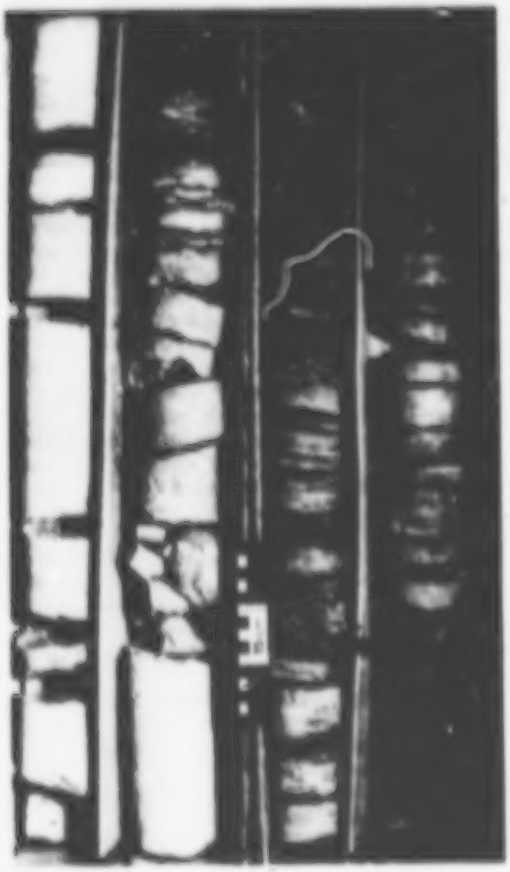


Photo 38. Large *Planolites* burrow in the Moosomin "B". (Tricent *et al.* Moosomin 8-32-14-31 well (Lsd. 8-32-14-31W1) at approximately 588.8 m)

Photo 39. (Left) Mud crack. Arrow points to mud crack in Moosomin "B" of Moosomin Member infilled with sandy olive-grey (5Y4/1) mudstone of Burrows "A". Contact is at approximately 666.5 m) (Tricent *et al.* Red Jacket 12-4-14-32 well (Lsd. 12-4-14-32W1) at approximately 666.5 m)

Photo 40. (Right) Mud crack. Oblique view of the underside of the mud crack in Photo 39.



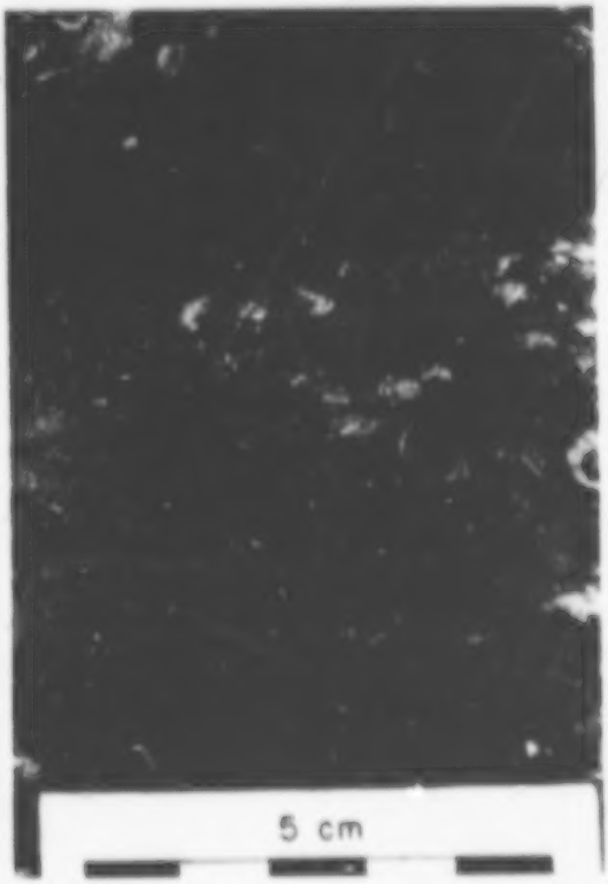


Photo 41. (Left) Moosomin "B" and Burrows "A" contact. The arrow points to the mud crack infilled contact at 666.5 m. (Tricent *et al.* Red Jacket 12-4-14-32 well (Lsd. 12-4-14-32W1) at 666.5 m)

Photo 42. (Right) Oncolitic sandstone. Arrow points to oncolite in an argillaceous sandstone in Burrows "B". (Tricent *et al.* Red Jacket 12-4-14-32 well (Lsd. 12-4-14-32W1) at approximately 658.6 m)

Appendix C: Selection of Core Descriptions

C.1 Introduction

The core descriptions presented in this appendix are a selection from 87 cored wells, and some 1500 m of available (as of March 1, 1990) cored Jurassic strata in the Wapella-Moosomin area. The wells presented here collectively represent all of the Jurassic units present in the study area with the exception of the Triassic-Jurassic (?) lower Watrous of the Watrous Formation. In these descriptions core depths have been adjusted to match geophysical log picks. It is important to note that some of the cores described in this appendix have been published previously by the present author (i.e. Kreis, 1987 and 1988). However, descriptions of these cores are somewhat modified to facilitate the stratigraphic subdivision invoked in this report.

The grading scale for grain size of sandstone is based on the Wentworth scale as follows:

Very coarse grained	- Grains 2 to 1 mm diameter
Coarse grained	- Grains 1 to 0.5 mm diameter
Medium grained	- Grains 0.5 to 0.25 mm diameter
Fine grained	- Grains 0.25 to 0.125 mm diameter
Very fine grained	- Grains 0.125 to 0.06 mm diameter

The sorting classification used follows Payne (1942):

Well sorted	- 90% in 1 or 2 size classes of the Wentworth scale
Moderately sorted	- 90% in 3 or 4 size classes of the Wentworth scale
Poorly sorted	- 90% in 5 or more size classes of the Wentworth scale

The following terms are used as a measure of mineral abundance:

Abundant	- greater than 10 percent
Minor	- 1 to 10 percent
Trace	- less than 1 percent

The colour chart used for description of the lithologies in this study was that of the Geological Society of America (GSA). New York, N.Y., second printing (1951). The term laminae defines layers less than 1 cm in thickness whereas the term bed defines layers 1 cm thick or greater.

C.2 Tide Water North Wapella Crown 14-22-15-1
(Lsd. 14-22-15-1W2)
K.B.: 1954 ft (595.6 m)

Cored Interval: 631.5-748.5 m

Rierdon Shale

2120.0-2183.0 (646.2-665.4) (Rec. 5.2 m)
Mudstone: light olive-grey (5Y6/1), slabby parting, hard, highly calcareous, trace to minor amounts of disseminated pyrite, fossiliferous. A sparse assemblage of belemnites, pelecypods (*Gryphaea nebrascensis*), ostracodes and ammonite shell fragments (*Kepplerites*?). Locally, mudstone grades quickly into claystone or siltstone beds up to 1.5 m thick. Lower contact missing.

Red Jacket Formation

Burrows Member

Burrows "B"

2183.0-2189.0 (665.4-667.2) (Rec. 0.91 m)
Sandstone: light olive-grey (5Y6/1), hard, very fine- to fine-grained, subangular to subrounded, clear quartz, poorly sorted, calcite cemented, silty, slightly argillaceous with minor amounts of very fine disseminated pyrite, a trace of glauconite and abundant broken-up well-worn *Gryphaea nebrascensis* and other unidentified pelecypods shells. Lower contact missing.

2189.0-2191.0 (667.2-667.8) (Rec. 0.23 m)
Mudstone: greenish-grey (5GY6/1) to dark greenish-grey (5GY4/1), hard, slabby parting, slightly calcareous to locally highly calcareous. Locally, abundant pelecypod molds (possibly *Pleuromya oblongata*? and *P. Simplex*?). Lower contact missing.

2191.0-2194.1 (667.8-668.8) (Rec. 0.92 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, slightly calcareous, swelling clays, abundant molds of pelecypods and the occasional ostracode. Moderately laminated with lenticular and parallel laminations of micaceous silt. Lower contact missing.

2194.1-2196.5 (668.8-669.5) (Rec. 0.73 m)
Sandstone: bioturbated, mottled, greenish-grey (5GY6/1) to light olive-grey (5Y6/1), hard, very fine- to fine-grained, clear quartz, subangular to subrounded, moderately sorted, well-cemented with calcite, locally abundant pelecypods and fine-grained disseminated pyrite. Very fine-grained pyrite locally replaces pelecypod shells. Disturbed greenish-grey (5GY6/1) calcareous mudstone laminations common over lower one-third. Lower contact sharp.

2196.5-2199.5 (669.5-670.4) (Rec. 0.80 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, calcareous. In gradational contact with interlaminated, silty sandstone below.

2199.5-2203.5 (670.4-671.6) (Rec. 1.20 m)
Sandstone: moderately to intensely bioturbated, highly interlaminated with mudstone and siltstone, light olive grey (5Y6/1), moderately friable, moderately sorted, very fine-grained, subangular, clear quartz, slightly calcareous, very silty (up to 30 percent), minor amounts of mica, slightly argillaceous, trace of indeterminate bone fragments and a few poorly preserved pelecypod shells. Minor patches of very fine-grained disseminated pyrite. A few sandy, calcite infilled, vertical fractures <1 mm across. Lower contact gradational.

Burrows 'A'

2203.5-2215.3 (671.6-675.2) (Rec. 3.60 m)
Claystone: medium grey (N5) to olive-grey (5Y4/1), hard, slabby to flaggy parting, locally slightly calcareous, minor parallel laminations with abundant pelecypod shells (possibly *P. oblongata* and *P. simplex*?). A few parallel laminations of micaceous silt and locally very fine-grained clear quartz. Sandy, olive-grey (5Y4/1) mudstone from this interval infills crack in the underlying greenish-grey (5GY6/1) unit. Lower contact sharp.

Moosomin Member

Moosomin 'B'

2215.3-2226.9 (675.2-678.8) (Rec. 3.00 m)
Sandstone (80 percent) and **Mudstone** (20 percent): moderately to intensely bioturbated, intermixed, mottled, light greenish-grey (5GY8/1) to greenish-grey (5GY6/1). Sandstone is hard, comprising, very fine- to fine-grained, subangular to subrounded, clear quartz, locally abundant poorly preserved pelecypods, and trace amounts of mica and indeterminate fish fragments. Moderately sorted, argillaceous (<5 percent), silty (<5 percent) and well-cemented with calcite. Locally abundant disseminated pyrite and rare nodules up to 2 cm across. Mudstone is greenish-grey (5GY6/1), hard, with slabby partings, locally abundant pelecypods, high calcite content, and up to 30 percent scattered, very fine to fine-grained, clear quartz. Patchy, pale yellowish brown (10YR6/2) oil-staining over lower 30 cm. Lower contact gradational.

2226.9-2231.0 (678.8-680.0) (Rec. 0.96 m)
Mudstone: interlaminated, greenish-grey (5GY6/1) to dark greenish-grey (5GY4/1), hard, slabby parting, calcareous. Laminated with micaceous siltstone and silty, micaceous, very fine to fine-grained, clear quartz sandstone which locally exhibits pale yellowish-brown (10YR6/2) oil-staining. Lower contact missing.

2231.0-2237.0 (680.0-681.8) (Rec. 1.47 m)
Mudstone: moderately bioturbated, mottled, yellowish-grey (5Y8/1) to greenish-grey (5GY6/1). Mudstone is hard, calcareous, with the occasional pelecypod mold and traces of mica and fine-grained disseminated pyrite. Limestone bed between approximately 2231.5-2232.1 (680.16-680.34 m). This limestone is very sandy and bioturbated over upper half, argillaceous, highly fossiliferous (abundant pelecypod shells), peloidal (indeterminate carbonate grains <1 mm across) with traces of unidentified bone fragments and patches of very fine-grained disseminated pyrite <0.5 cm across. Mudstone is gradational with argillaceous, silty, micaceous, poorly sorted, very fine-grained sandstone over lower 40 cm. Lower contact missing.

2237.0-2243.5 (681.8-683.8) (Rec. 1.43 m)
Sandstone: yellowish-grey (5Y8/1) to greenish-grey (5GY6/1), hard, very fine- to fine-grainert, subangular to subrounded, clear quartz, argillaceous, silty, trace of mica, trace of very fine-grained disseminated pyrite. Small-scale ripples are observed at several intervals. Mudstone interbed between approximately 2239.5-2240.5 (682.6-682.9 m). The mudstone is greenish-grey (5GY6/1), slightly dolomitic and exhibits trace amounts of mica. Lower contact gradational.

2243.5-2257.0 (683.8-687.9) (Rec. 3.11 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, slightly calcareous to calcareous, trace of mica, trace of pyrite, trace of indeterminate fish(?) bone fragments. Moderately bioturbated sandstone interbeds up to 40 cm thick found between approximately 2247.0-2251.0 (684.9-686.1). Sandstone is composed of very fine to fine-grained, clear quartz, is well-cemented with calcite, slightly argillaceous, silty (up to 30 percent) with trace amounts of pyrite, carbonaceous fragments and indeterminate bone fragments. Lower contact gradational.

2257.0-2266.0 (687.9-690.7) (Rec. 2.26 m)
Mudstone (60 percent) **and Sandstone** (40 percent): Interbedded and interlaminated. Sandstone is yellowish-grey (5Y8/1) and dusky yellowish-brown (10YR2/2) where oil stained, comprised of moderately hard, moderately sorted, very fine-grained, subangular clear quartz. Shows minor to abundant amounts of mica and silt, trace amounts of carbonaceous detritus and very fine disseminated pyrite, and is moderately calcite-cemented. Sandstone interbeds are up to 8 cm (?) thick. Interlaminations of silty and micaceous very fine-grained clear quartz. Mudstone is olive-grey (5Y4/1), is micromicaceous and shows trace amounts of carbonaceous detritus. Lower contact gradational.

Moosomin 'A'

Moosomin "A2"

2266.0-2292.0 (690.7-698.6) (Rec. 4.11 m)
Sandstone (60 percent) **and Mudstone** (40 percent): interbedded and interlaminated. Sandstone is yellowish-grey (5Y8/1) to dusky yellowish-brown (10YR2/2) where oil stained. It is moderately hard to hard, moderately to poorly sorted, made up of very fine to fine-grained, subangular to subrounded, clear quartz. It is moderately to well-cemented with calcite, silty (up to 30 percent) and slightly argillaceous (<3 percent), with trace amounts of mica (flakes up to 1 mm thick), pyrite (nodules up to 3 mm across) and carbonaceous fragments. Sandstone is interlaminated and interbedded with greenish-grey (5GY6/1) to olive-grey (5Y4/1) mudstone. The

mudstone is locally slightly calcareous, sandy (up to 30 percent very fine- to fine-grained, clear quartz) and highly interlaminated with siltstone and silty, micaceous, very fine-grained sandstone. Mudstone interbeds range up to 90 cm in thickness. Silty, micaceous and carbonaceous laminations become increasingly common over lower 3 metres. Lower contact very gradational.

2292.0-2311.0 (698.6-704.4) (Rec. 3.78 m)
Sandstone (70 percent) **and Mudstone** (30 percent): interbedded and interlaminated. Sandstone ranges in colour from yellowish-grey (5Y8/1) to light olive-grey (5Y6/1) and dark yellowish-brown (10YR4/2) where oil stained. The sandstone is generally friable but local calcite cemented zones up to 15 cm thick are observed. It is moderately sorted containing very fine to fine-grained, subangular to subrounded, clear quartz, with locally abundant mica and carbonaceous fragments, and trace amounts of pyrite. Abundant interlaminations of argillaceous, silty, micaceous and slightly carbonaceous sandstone and occasionally olive-grey (5Y4/1), sandy mudstone. Mudstone interbeds up to 30 cm in thickness with abundant interlaminations of silty, micaceous, and carbonaceous, very fine-grained clear quartz. The mudstone itself has as much as 40 percent, scattered, very fine-grained, clear quartz. Lower contact missing.

Moosomin "A1"

2311.0-2317.0 (704.4-706.2) (Rec. 1.31 m)
Sandstone: yellowish grey (5Y8/1) with oil-stained patches of dark yellowish-brown (10YR4/2). It is moderately friable, moderately to well sorted, composed of very fine- to fine-grained, subangular to subrounded, clear quartz. There are trace amounts of; fine-grained disseminated pyrite, mica and carbonaceous fragments. Locally, abundant interlaminations of argillaceous, silty, micaceous and carbonaceous material. There are occasional interbeds of sandy (up to 30 percent very fine- to fine-grained, clear quartz) olive-grey (5Y4/1) mudstone of less than 15 cm thickness. Lower contact missing.

2317.0-2323.0 (706.2-708.1) (Rec. 0.82 m)
Sandstone: interlaminated, yellowish-grey (5Y8/1) to pale yellowish-brown (10YR6/2) where oil-stained. It is friable, moderately to poorly sorted, containing very fine to fine-grained, subangular to subrounded, clear quartz with up to 30 percent silt and minor quantities of mica and carbonaceous fragments. Interlaminations of highly argillaceous, micaceous and carbonaceous material is common. Lower contact missing.

2323.0-2349.0 (708.1-716.0) (Rec. 4.58 m)
Sandstone: yellowish-grey (5Y8/1) to pale yellowish-brown (10YR6/2) where oil-stained. It is friable, moderately to well sorted, composed of very fine- to fine-grained, subangular to subrounded, clear quartz. Generally it is silty (up to 20 percent) with minor mica (flakes up to 1 mm across) and trace amounts of fine-grained disseminated pyrite and carbonaceous fragments. Locally, there are parallel to wavy interlaminations of slightly argillaceous, micaceous and carbonaceous material. Sandy, micaceous and carbonaceous mudstone interbeds measuring up to 10 cm thick are common between approximately 2328.0-2338.0 (709.6-712.6). Locally these mudstones are interlaminated with silty, micaceous sandstone. Lower 40 cm also interbedded with olive-grey (5Y4/1) mudstone up to 10 cm thick. Lower contact missing.

2349.0-2360.0 (716.0-719.3) (Rec. 2.29 m)
Sandstone: light olive-grey (5Y6/1) to dark yellowish-brown (10YR4/2) in patchy oil-stained areas. Sandstone is hard to moderately friable, well sorted, composed of very fine- to fine-grained, subangular to subrounded, clear quartz with trace to minor amounts of mica and carbonaceous fragments (with the occasional carbonaceous wood fragment up to 4 cm across). It is well-cemented with calcite over upper half exhibiting high angle planar (up to 20 degrees) and current ripple bedding. Laminations are defined by abundant mica (flakes up to 1 mm across) and organic detritus.

Lower contact missing.

Rocanville Member

Rocanville "B"

2360.0-2364.5 (719.3-720.7) (Rec. 0.81 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, moderately to locally highly calcareous, sandy (up to 10 percent scattered very fine- to fine-grained quartz). A 2 cm thick layer of calcite and slightly oxidized, pyrite cemented, poorly sorted, fine-grained, subrounded, clear quartz sandstone occurs at the top of the material recovered in this interval. This sandstone layer is cemented with calcite and slightly oxidized pyrite. Lower contact is sharp and irregular.

2364.5-2373.5 (720.7-723.4) (Rec. 2.29 m)
Limestone: yellowish-grey (5Y8/1) to light olive-grey (5Y6/1), very hard, dolomitic, highly argillaceous, slightly sandy (up to 5 percent scattered, very fine to fine-grained, clear quartz). Dark greenish-grey (5GY4/1), calcareous mudstone break between approximately 2367.5-2369.0 (721.6-722.1). Upper contact displays a 10 cm long vertical fracture infilled with overlying greenish-grey (5GY6/1) mudstone. Lower contact sharp.

2373.5-2376.0 (723.4-724.2) (Rec. 0.46 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, calcareous, sandy (up to 5 percent scattered, very fine- to fine-grained, clear quartz). Lower contact missing.

2376.0-2378.4 (724.2-724.9) (Rec. 0.74 m)
Limestone: pale yellowish-brown (10YR6/2), very hard, dolomitic, slightly argillaceous, trace to minor amounts of pyrite (commonly in patches of <0.5 cm across), traces of mica and scattered, very fine-grained, clear quartz. A few poorly preserved pelecypod shells and a trace of indeterminate fish(?) bone fragments are also present. Lower contact of unit gradational.

2378.4-2379.6 (724.9-725.3) (Rec. 0.34 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, becomes increasingly calcareous towards top, one large (4 cm across) mold of pelecypod shell fragment

and trace amounts of indeterminate bone fragments. Occasional laminations of silty, micaceous, very fine- to fine-grained, subangular to subrounded, clear quartz. Lower contact poorly preserved.

2379.6-2390.0 (725.3-728.5) (Rec. 1.89 m)
Sandstone: yellowish-grey (5Y8/1) to dark yellowish-brown (10YR4/2) in small (< 3 cm) patches of oil staining. It is moderately friable, moderately to well sorted, containing fine- to mudium-grained, subangular to subrounded, slightly calcite-cemented, clear quartz with trace to minor amounts of mica. Excellent porosity in a well sorted, medium-grained interval between approximately 2383.0-2385.0 (726.3-727.0). Becomes siltier and finer grained above and below this interval. Lower contact gradational.

2390.0-2395.5 (728.5-730.1) (Rec. 1.07 m)
Sandstone and Siltstone: interlaminated, interbedded, yellowish-grey (5Y8/1) to light olive-grey (5Y6/1), moderately hard. Sandstone is moderately hard, moderately sorted, slightly calcite cemented, composed of very fine-grained, subangular, clear quartz with abundant silt (up to 50 percent), minor amounts of mica and a few pyrite nodules (up to 1.5 cm across). Abundant interlaminations and interbeds of sandy (up to 30 percent very fine-grained, clear quartz), argillaceous siltstone over lower two-thirds. Lower contact gradational.

2395.5-2397.7 (730.1-730.8) (Rec. 0.55 m)
Mudstone: olive-grey (5Y4/1), hard, slabby parting, trace amounts of very fine-grained disseminated pyrite, carbonaceous fragments and indeterminate bone fragments. Becomes calcareous over lower 15 cm. Lower contact missing.

2397.7-2400.0 (730.8-731.5) (Rec. 0.65 m)
Sandstone: white (N9) to yellowish-grey (5Y8/1), moderately friable, moderately calcite-cemented, very fine-grained, subangular, clear quartz, showing a trace of mica and locally abundant pyrite nodules (nodules up to 3 cm across present over lower half). Becomes increasingly interlaminated with very silty and slightly argillaceous material over lower two-thirds. Lower contact sharp.

2400.0-2401.5 (731.5-732.0) (Rec. 0.15 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, calcareous with a trace of pyrite and very fine-grained, scattered quartz. Lower contact missing.

2401.5-2403.0 (732.0-732.4) (Rec. 0.34 m)
Limestone: light olive-grey (5Y6/1) to yellowish-grey (5Y8/1), hard, dolomitic and argillaceous, with trace amounts of mica and very fine-grained disseminated pyrite. Grades up from a calcareous, greenish-grey (5GY6/1) mudstone over lower 15 cm. Lower contact missing.

2403.0-2405.2 (732.4-733.1) (Rec. 0.62 m)
Limestone: yellowish-grey (5Y8/1), hard, dolomitic, slightly argillaceous, locally abundant bean-shaped (unidentified) ostracodes and trace amounts of mica and pyrite. Lower contact of unit gradational.

2405.2-2406.9 (733.1-733.6) (Rec. 0.52 m)
Siltstone: greenish-grey (5GY4/1), hard, slabby parting, argillaceous, minor to locally abundant mica and sandy (up to 30 percent very fine-grained, clear quartz). Lower contact of unit gradational.

2406.9-2410.0 (733.6-734.6) (Rec. 0.91 m)
Sandstone: interlaminated, yellowish-grey (5Y8/1), moderately hard, and moderately to poorly sorted. It is comprised of very fine-grained, subangular, clear quartz and is argillaceous, very silty (locally up to 40 percent) with minor to abundant mica and a trace of carbonaceous fragments over lower half. Grades into a siltstone over lower 30 cm. Lower contact of unit missing.

Lower Gravelbourg

Unit B

2410.0-2410.7 (734.6-734.8) (Rec. 0.20 m)
Limestone: olive-grey (5Y4/1), very hard. This limestone is dominated by ovate to sub-spherical peloids up to 2 mm in length and 1 mm across. The peloids contain significant amounts of silt-sized pyrite. The limestone matrix is slightly argillaceous with minor pyrite and a trace of mica. The uppermost 1.5 cm interval contains: calcareous, olive-grey (5Y4/1) mudstone, and rounded, medium- to coarse-grained olive-black (5Y2/1), carbonate grains (peloids), silt (approximately 20 percent) and trace amounts of glauconite in a olive-grey (5Y4/1) matrix. This is immediately underlain by a 2 to 3 mm layer of fibrous calcite and pyrite. Lower contact of unit sharp.

2410.7-2416.5 (734.8-736.6) (Rec. 1.77 m)
Limestone: light olive-grey (5Y6/1), very hard, slightly argillaceous with trace amounts of mica and scattered, very fine-grained, clear quartz. Becomes increasingly interlaminated over lower half with silty, slightly argillaceous laminae with abundant silt-sized disseminated pyrite. Lower contact sharp, defined by a 0.5 cm band of interlaminated, peloidal and sandy (up to 30 percent very fine- to fine-grained, clear quartz) mudstone with abundant disseminated pyrite and trace amounts of mica and glauconite.

2416.5-2431.5 (736.6-741.1) (Rec. 2.92 m)
Mudstone: olive-grey (5Y4/1), hard, platy to fissile parting, calcareous with abundant thin-shelled pelecypods cm across (*Modiolus*?). Pelecypods are so abundant they form laminae < 1 mm thick which are composed entirely of crushed shells. An interbed of olive-grey (5Y4/1), highly fossiliferous (abundant pelecypods), sandy (up to 20 percent very fine-grained, clear quartz) limestone with abundant very fine-grained disseminated pyrite, and a trace of mica and glauconite occurs, between approximately 2421.5-2422.0 (738.1-738.2). Lower contact sharp, defined by a 10 cm band of highly fossiliferous (pelecypod shell hash), glauconitic, peloidal, pyritic and sandy (up to 10 percent very fine- to fine-grained, clear quartz) mudstone at base.

2431.5-2432.2 (741.1-741.32) (Rec. 0.22 m)
Limestone: light-olive grey (5Y6/1), very hard and mas-

sive. Rare vertical hair-line fractures are lined with very fine-grained pyrite. Lower contact sharp and irregular, defined by a 1.5 cm thick band of calcite- and pyrite-cemented, fine-grained, argillaceous sandstone.

2432.2-2434.0 (741.1-741.9) (Rec. 0.61 m)
Mudstone: light-olive grey (5Y6/1), hard, silty to locally sandy (up to 40 percent very fine grained, clear quartz) with minor very fine-grained disseminated pyrite, and trace amounts of mica and glauconite. Lower contact of unit missing.

2434.0-2437.0 (742.2-742.8) (Rec. 0.55 m)
Sandstone: light olive-grey (5Y6/1), hard and moderately sorted. It is composed of very fine-grained, subangular to subrounded, clear quartz and is calcite cemented. Has minor amounts of mica, very fine-grained disseminated pyrite (occasional patch cm across) and a trace of carbonaceous fragments. It becomes increasingly argillaceous and silty towards base. Lower contact appears gradational.

2437.0-2440.0 (742.8-743.7) (Rec. 0.46 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby parting, moderately calcareous, sandy (up to 30 percent very fine- to fine-grained, clear quartz) with minor mica, and trace amounts of carbonaceous fragments and disseminated pyrite. Lower contact missing.

2440.0-2444.0 (743.7-744.9) (Rec. 1.07 m)
Siltstone: light olive-grey (5Y6/1), hard, calcareous, argillaceous with traces of mica and pyrite. Calcareous, greenish-grey (5GY6/1) mudstone break between approximately 2441.0-2441.5 (744.0-744.2). Lower contact gradational.

2444.0-2451.5 (744.9-747.2) (Rec. 0.91 m)
Mudstone: light olive-grey (5GY6/1), hard, flaggy parting, highly calcareous (approaching limestone composition). Lower contact of unit not preserved.

2451.5-2452.0 (747.2-747.4) (Rec. 0.23 m)
Sandstone: greenish-grey (5GY6/1), moderately hard, moderately sorted to poorly sorted, very fine- to fine-grained, clear quartz, argillaceous, silty (up to 30 percent), minor mica, minor to locally abundant glauconite and pyrite, minor subrounded very pale-orange (10YR8/2) carbonate fragments and trace to minor amounts of greyish-blue (5PB5/2) to dusky-blue (5PB3/2) subrounded to rounded chalcedonic chert nodules up to 3 mm across. Lower contact of unit sharp and irregular.

Upper Watrous

2452.0-2459.0 (747.4-749.5) (Rec. 0.31 m)
Dolomite and Anhydrite: interbedded. Dolomite is very pale-orange (10YR8/2) to light olive-grey (5Y6/1) while the anhydrite is light bluish-grey (4b7/1) to light grey (N7). Dolomite is massive, brecciated, with fractures infilled by gypsum. Interbeds composed of light bluish-grey (4b7/1) to light grey (N7) anhydrite intermixed with greyish-blue (5PB5/) to dusky blue (5PB3/2) chalcedonic chert. Locally, euhedral, bipyramidal quartz crystals and chalcedonic chert nodules occur as apparent void-fill in the dolomite. Very poor recovery.

C.3 Tidewater Wapella No. 6-33
(Lsd. 6-33-14-1W2)
K.B.: 1973 ft (601.3 m)

Cored interval: 706.2-763.8 m

Red Jacket Formation

Moosomin Member

Moosomin 'B'

2317-2327 ft. (706.2-709.3 m) (Rec. 3.0 m).
Sandstone: light greenish-grey (5GY8/1) to pale yellowish-brown (10YR6/2), where oil stained, moderately hard, very fine-grained, subangular, clear quartz, moderately to poorly sorted, weakly calcite-cemented, very silty and argillaceous with abundant amounts of mica and rare pyrite nodules up to 2.5 cm across. Locally interlaminated with silty, micaceous and argillaceous material. Patchy oil stain over lower half. Lower contact gradational.

2327-2340 ft. (709.3-713.2 m) (Rec. 2.4 m).
Sandstone: light olive-grey (5Y6/1) to dark yellowish-brown (10YR4/2) where oil stained over upper 1 m, moderately friable, very fine- to fine-grained, subangular to subrounded, clear quartz, well sorted, weakly calcite-cemented, with minor silt and mica flakes up to 1 mm across. Becomes increasingly interlaminated with silty, micaceous and argillaceous material over lower 1 m. Lower contact missing.

2340-2363 ft. (713.2-720.2 m) (Rec. 6.6 m).
Mudstone: interbedded and interlaminated, light olive-grey (5Y6/1) to olive-grey (5Y4/1), hard, blocky parting. Interbeds and interlaminations of yellowish-grey (5Y8/1) to pale yellowish-brown (10YR6/2) where oil stained, very fine-grained, subangular, clear quartz, poorly sorted, with minor to abundant amounts of silt, mica, and argillaceous material, and trace to minor amounts of carbonaceous detritus. Interbeds of sandstone are up to 4 cm thick. Lower half metre is variegated pale reddish-brown (10R5/4) to dusky-yellow (5Y6/4). Lower contact sharp and irregular.

Moosomin 'A'

2363-2370.5 ft. (720.2-722.5 m) (Rec. 2.3 m).
Sandstone: yellowish-grey (5Y8/1), very hard, very fine- to fine-grained, subangular to subrounded, clear quartz, moderately to well sorted, well-cemented with dolomite over upper half becoming calcite-cemented over lower half, minor silt and mica. Pyrite nodules up to 4 cm across common over upper 10 cm. Becomes silty, moderately bioturbated and interlaminated with light olive-grey (5Y6/1) calcareous mudstone over lower half. Lower contact gradational.

2370.5-2400 ft. (722.5-731.5 m) (Rec. 8.4 m).
Sandstone (60 percent) **and Siltstone** (40 percent): interbedded and interlaminated. Yellowish-grey (5Y8/1) to pale yellowish-brown (10YR6/2) sandstone interbeds up 1.5 m thick, composed of very fine- to fine-grained, subangular to subrounded, clear quartz. They are moderately to well sorted, weakly calcite-cemented, and show minor amounts of silt, mica and medium grain size pellet-like masses (fecal pellets?) of glauconite. The siltstone is light olive-grey (5Y6/1) to olive-grey (5Y4/1), sandy (up to 30 percent very fine-grained clear quartz) with trace to abundant amounts of mica of carbonaceous detritus. An interbedded and interlaminated siltstone/mudstone break occurs between 727.1 to 728.5 m. The olive-grey (5Y4/1) mudstone interbeds are up to 10 cm thick and show small (less than 1 cm) pelecypod molds (*Pleuromya*?). Lower contact missing.

Rocanville Member

Rocanville "C"

2400-2401.2 (731.5-731.9 m) (Rec. 0.42 m).
Siltstone: light greenish-grey (5GY8/1) to yellowish-grey (5Y8/1). This siltstone is interlaminated with silty and micaceous very fine-grained clear quartz sandstone and light-olive grey (5Y6/1) calcareous mudstone. Lower contact poorly preserved but appears to be sharp and irregular.

2401.2-2406 ft. (731.9-733.3 m) (Rec. 1.0 m).
Limestone: very pale-orange (10YR8/2) to pale yellowish-brown (10YR6/2), very hard and well-cemented with calcite. It is composed of oolites (up to 50 percent), very fine- to fine-grained subangular clear quartz (up to 50 percent) and bioclastic debris. Crinoid ossicles (*Pentacrinus*?) and pelecypod shell fragments are recognized. Many of the oolites have a single very fine- or fine-grained clear quartz grain in their centre. Lower contact missing.

2406-2420 ft. (733.3-737.6 m) (Rec. 3.5 m).
Siltstone: light olive-grey (5Y6/1), hard, sandy up to 30 percent very fine-grained clear quartz with abundant mica. Greenish-grey (5GY6/1) calcareous mudstone breaks up to 30 cm thick at top and bottom of interval. Interbeds of siltstone interlaminated mudstone up to 50 cm thick. Lower contact missing.

Rocanville "B"

2420-2458 ft. (737.6-749.2 m) (Rec. 8.8 m).
Siltstone: variegated, greenish-grey (5GY6/1), greenish-orange (10YR7/4) to pale reddish-brown (10R5/4), hard with slabby parting and dolomitic. Mudstone interbeds up to 1 m thick. Mudstone cracks are noted at approximately 745.2 m. Very fine- to fine-grained, moderately to well sorted, silty and micaceous sandstone showing small-scale current ripple bedding between 738.2 and 740.0 m. Pale yellowish-brown (10YR6/2) argillaceous dolostone interbed between 746.5 and 747.7 m. Rare argillaceous limestone interbeds up to 10 cm over lower 2 m. Lower contact missing.

2458-2475 ft. (749.2-754.4 m) (Rec. 2.3 m)
Sandstone: yellowish-grey (5Y8/1) to pale yellowish-brown (10YR6/2) where oil stained, hard to moderately friable, variably calcite-cemented but better cemented over upper 1 m. This sandstone is composed of fine-grained subangular to subrounded, moderately sorted clear quartz. Locally interlaminated with very silty, micaceous and argillaceous material, have pyrite nodules up to 0.5 cm across. Small-scale wave and current ripples are observed locally, as are poorly defined *Skolithos*(?) burrows. Lower contact poorly preserved but appears gradational.

2475-2482 ft. (754.4-756.5 m) (Rec. 2.0 m).
Siltstone: light olive-grey (5Y6/1) to olive-grey (5Y4/1) hard, becomes calcareous over lower 1 m rare pyrite nodules up to 3 cm across. Bone bed (1 cm thick) composed of indeterminate bone fragments up to 3 mm long at approximately 756.0 m. Lower contact gradational.

2482-2492 ft. (756.5-759.6 m) (Rec. 2.6 m).
Sandstone: light olive-grey (5Y6/1) hard to moderately friable, fine-grained, subangular to subrounded clear quartz, moderately to well sorted, variably calcite-cemented but better cemented over upper 2 m. Mostly massive and weakly laminated becoming increasingly interlaminated with silty, micaceous and argillaceous material. Lower contact missing.

Rocanville "A"

2492-2495 ft. (759.6-760.5 m) (Rec. 0.6 m).
Siltstone: light olive-grey (5Y6/1) to olive-grey (5Y4/1), hard, sandy (up to 30 per cent very fine-grained clear quartz), abundant mica and carbonaceous detritus. Trace amounts of finely disseminated pyrite and rare pyrite nodules. Lower contact sharp.

Lower Gravelbourg

Unit B

2495-2495.6 ft. (760.5-760.65 m) (Rec. 0.15 m).
Mudstone: olive-grey (5Y4/1), hard, calcareous, trace of carbonaceous detritus. A 6 cm band of pyritized peloidal (oolitic) material at base. Pyrite is very fine and disseminated. Lower contact sharp.

2495.6-2501 ft. (760.65-762.3 m) (Rec. 1.35 m).
Limestone: light olive-grey (5Y6/1), hard, argillaceous, poorly laminated and silty, with abundant very fine-disseminated pyrite. Interbeds of oolitic, peloidal and bioclastic material (indeterminate pelecypod shells) up to 35 cm thick. Lower contact not preserved but appears sharp.

2501-2506 ft. (762.3-763.8 m) (Rec. 0.2 m).
Mudstone: olive-grey (5Y4/1), hard, platy parting, very calcareous, abundant thin-shelled pelecypods (*Modiolus*?) and other indeterminate pelecypods.

C.4 CNW Wapella 6-2-15-1
(Lsd. 6-2-15-1W2)
K.B.: 595.5 m

Cored interval: 729.0-738.0 m; 739.0-747.0 m

Red Jacket Formation

Moosomin "A"

Moosomin "A1"

730.0-740.45 (Rec. 8.2 m).
Siltstone: olive-grey (5Y4/1), platy parting, abundant mica and carbonaceous detritus, abundant very fine-disseminated pyrite and minor pyrite nodules up to 4 cm across. Interlaminated with fine-grained angular to subangular clear quartz. Sandstone interbeds up to 15 cm thick, composed of poorly sorted, fine- to medium-grained, subangular to rounded clear quartz with patchy calcite cement. Some of these sandstone interbeds exhibit wispy discontinuous laminations and poorly defined small-scale ripple bedding. The contacts between sandstone interbeds and siltstone are everywhere sharp. Lower contact sharp.

740.45-742.15 (Rec. 1.7 m).
Sandstone: dark yellowish-brown (10YR4/2) due to oil staining, moderately hard, fine to medium grained, subangular to subrounded, moderately to well sorted, minor silt, trace of pyrite, variably calcite-cemented. These sandstones show low-angle and high-angle planar (up to 30°) cross-stratification. Silt, mica argillaceous and carbonaceous material define lamina in these sandstone. Some of the high-angle bedforms are at opposing angles of inclination suggesting bidirectional flow.

Two 5 cm thick interbeds of olive-grey (5Y4/1) siltstone occur in the lower 40 cm. Siltstone clasts up to 3 cm across occur in lower 8 cm. Lower contact sharp.

742.15-742.5 (Rec. 0.35 m).
Siltstone: olive-grey (5Y4/1), platy parting, abundant mica and minor carbonaceous detritus, minor interlaminations of silty very fine- to fine-grained clear quartz. A 5 cm interbed of moderately sorted fine- to medium-grained sandstone near base. Lower contact sharp.

742.5-743.9 (Rec. 1.1 m).
Sandstone: dark yellowish-brown (10YR4/2) due to oil staining, moderately friable, medium-grained, subrounded to rounded, clear quartz, moderately to poorly sorted, minor silt, variably calcite-cemented. Scattered siltstone clasts and carbonaceous fragments. Lower 20 cm shows siltstone pebbles and is very poorly sorted. Lower contact sharp.

Rocanville Member

Rocanville "B"

743.9-745.9 (Rec. 2.0 m).
Siltstone: light olive-grey (5Y6/1, to olive-grey (5Y4/1), hard, micaceous, sandy (up to 40 percent very fine-grained clear quartz). Lower contact sharp.

745.9-746.6 (Rec. 0.70 m).
Sandstone: light olive-grey (5Y6/1) to pale yellowish-brown where oil stained in patches, moderately friable over upper 20 cm becoming increasingly calcite-cemented over lower half. Lower contact gradational.

746.6-748.0 (Rec. 1.4 m).
Sandstone: light olive-grey (5Y6/1), hard, fine-grained clear quartz, moderately to well sorted, abundant mica, minor pyrite, well-cemented with calcite and dolomite. Many of the mica flakes are various shades of green possibly indicating incomplete glauconitization. Low-angle and high-angle planar (up to 30°) cross-stratification observed in lower 60 cm.

C.5 TRICENT ET AL. MOOSOMIN 4-28-14-31
(Lsd. 4-28-14-31W1)
K.B. 556.0 m

Cored intervals: 588.5-597.5 m; 599.0-607.0 m; 649.0-702.0 m.

Burrows Member

Burrows "A"

588.5-589.6 (Rec. 1.1 m)
Claystone: medium-grey (N5), slabby parting, weakly calcareous, slightly bentonitic, abundant small (< 1 cm average) pelecypods *Pleuromya simplex*? and *P. oblongata*? occur in thin 2-3 mm pavements. Lower 15 cm grades upwards from a highly interlaminated micaceous siltstone/claystone becoming bioturbated and sandy (very fine grained) over lower 5 cm. Lower contact poorly preserved but appears to be sharp.

Moosomin Member

Moosomin "B"

589.6-591.3 (Rec. 1.7 m)
Sandstone and Mudstone: Bioturbated, mottled, greenish-grey (5GY6/1) mudstone and very light grey (N8) sandstone. Sandstone is hard, composed of very fine-grained clear quartz, subangular to subrounded, well sorted, well-cemented with calcite, minor mica, minor pyrite, slightly silty. Mudstone component is calcareous, with swelling clays and is locally very sandy. The interval is highly bioturbated giving it a mottled appearance. Locally, bioturbation appears to have homogenized the sediments. Lower contact sharp, defined by contact with oil stained underlying sandstone.

591.3-592.1 (Rec. 0.8 m)
Sandstone: pale yellowish-brown (10YR6/2) to yellowish-grey (5Y8/1) friable to moderately calcite-cemented over upper 5 cm, very fine-grained clear quartz, subangular to subrounded, moderately sorted, silty, minor mica. The interval becomes very silty, slightly

bioturbated and interlaminated with argillaceous silt and mudstone over the lower 45 cm. *Planolites* is observed in the lower 35 cm. Upper 40 cm is oil stained exhibiting good to excellent intergranular porosity. Lower contact gradational.

592.0-594.8 (Rec. 2.8 m)
Sandstone: light greenish-grey (5GY8/1), hard, very fine- to fine-grained clear quartz, subangular to subrounded, poorly sorted, highly calcareous, argillaceous, silty, minor mica, minor pyrite, minor indeterminate carbonate grains up to fine grain size. Moderately to highly bioturbated. Weakly preserved remnants of inclined bedding up to 30°. Only slightly bioturbated over lower 20 cm with oil stained interbeds. Lower contact gradational.

594.8-597.5 (Rec. 2.7 m)
Sandstone: dark yellowish-brown (10YR4/2), friable, very fine- to fine-grained clear quartz, subangular to subrounded, well sorted. Excellent intergranular porosity, heavily oil saturated.

599.0-604.9 (Rec. 5.9 m)
Sandstone: dark yellowish-brown (10YR4/2) to light grey (N7), friable to locally hard, very fine- to fine-grained clear quartz, subangular to subrounded, well sorted, minor mica, slightly argillaceous, very slightly to moderately calcite-cemented between 599.0 and 601.0 m. Becoming increasingly calcite-cemented, silty and micaceous towards base with numerous less cemented breaks showing oil staining. The better cemented intervals exhibit thin argillaceous, micaceous, slightly carbonaceous inter-laminations and the occasional medium grey (N5) mudstone drape. These intervals also seem to demonstrate a weak ripple bedding. Lower contact sharp, possibly scoured.

604.9-605.6 (Rec. 0.7 m)
Sandstone: light greenish-grey (5GY 8/1) to greenish-grey (5GY 6/1), friable to moderately consolidated, very-fine- to fine-grained clear quartz, subangular to subrounded, moderately sorted, slightly to moderately calcite-cemented, slightly argillaceous, locally very silty. Some interlamination with very argillaceous silt and mudstone.

605.6-607.0 (Rec. 0.0 m)
Core Missing.

Lower Gravelbourg

Unit B

649.0-663.7 (Rec. 14.7 m)
Limestone: very light grey (N8) to light grey (N7) and dark yellowish-brown (10YR4/2), hard, locally up to 50 percent, very fine- to fine-grained clear quartz, subangular-rounded, up to 30 percent medium-grained oolite and peloidal material, slightly silty, very slightly argillaceous, minor glauconite, trace of mica, trace of chert, very fine crystalline calcite matrix. Oil stained patches between 649.9-652.5 m exhibit fair intergranular porosity. Numerous microstylolites and the occasional poorly developed large (0.5 cm wide), silty, argillaceous, stylolite. Lower contact sharp.

663.7-663.8 (Rec. 0.1 m)
Limestone: light olive-grey (5Y6/1), hard, argillaceous, dolomitic, trace of chert, less than 5 percent floating very fine- to fine-grained quartz. Becomes highly argillaceous and sandy over lower 2 cm. Lower contact gradational.

663.8-663.9 (Rec. 0.1 m)
Sandstone: light olive-grey (5Y6/1) and dark yellowish-brown (10YR4/2), hard, very fine- to fine-grained clear quartz, subangular to subrounded, moderately well sorted, calcite-cemented, slightly argillaceous, trace of chert. Lower contact sharp.

663.9-664.1 (Rec. 0.2 m)
Sandstone: light olive-grey (5Y6/1), hard, very fine- to fine-grained clear quartz, subangular to rounded, poorly sorted, silty, highly argillaceous, abundant coarse grain to pebble size, rounded to well-rounded chert. Lower contact sharp, erosive and disconformable, incorporating weathered dolomite from below.

664.1-665.1 (Rec. 1.0 m)
Conglomerate: greyish-blue (5PB5/2) and very pale orange (10YR8/2). This interval is composed of coarse grain to pebble size, subangular to rounded clasts of dolostone and chert with scattered quartz a minor component. Slightly sucrosic to cryptocrystalline dolomite matrix. Numerous oil-stained microfractures and oil-stained patches observed. Lower contact appears sharp.

Upper Watrous

665.1-681.5 (Rec. 16.4 m)
Anhydrite, Dolostone and Dolomitic Mudstone: This interval is interbedded and multicoloured; very pale orange (10YR8/2) greyish-blue (5PB5/2) light olive-grey (5Y6/1), and greenish-grey (5GY6/1). Interbeds of thick (up to 40 cm) greyish-blue translucent anhydrite, very pale orange dolostone (up to 75 cm thick) and light olive-grey (5Y6/1) to greenish-grey (5GY6/1) dolomitic mudstone make up this interval. These interbeds are moderately brecciated with secondary gypsum infilling fractures. Much of the anhydrite present is nodular and coalescing. The interval between (679.6-680.9 m) is a dark reddish-brown (10R3/4) mudstone.

Mississippian

681.5-685.0 (Rec. 3.5 m)
Anhydrite and Limestone: greyish-blue (5PB5/2) translucent anhydrite, infilling voids within the very pale orange (10YR8/2) to greyish orange-pink (5YR7/2) and pale yellowish-brown (10YR6/2) limestone. The upper 2.5 m exhibits abundant black angular chert and chertified limestone fragments. Fractures are infilled with secondary gypsum. Oil staining in a few patches in lower half of interval.

685.0-702.0 (Rec. 8.0 m)
Limestone: very pale orange (10YR8/2) to greyish-pink

(10YR7/2) and moderate yellowish-brown (10YR5/4). Approximately 2/3 of the interval, between 689.0-702.0 m is missing.

C.6 TRICENT ET AL. RED JACKET 12-4-14-32
(Lsd. 12-4-14-32W1)
K.B. 581.1 m

Cored interval: 646.7-659.0 m and 663.9-672.4 m

Rierdon Shale

646.7-653.1 (Rec. 6.4 m)
Mudstone: light olive-grey (5Y6/1), slabby parting, hard, highly calcareous, minor disseminated pyrite, fossiliferous (belemnites, occasional pelecypod and ammonite fragments (*Kepplerites*?). Lower contact sharp.

653.1-653.3 (Rec. 0.2 m)
Sandstone: pale yellowish-brown (10YR6/2) very fine- to fine-grained clear quartz, subangular to subrounded, poorly sorted, very silty, highly argillaceous, highly calcareous, abundant (up to 50 percent) fine- to medium-grained ironstone "oolite", minor mica, minor pyrite, abundant broken-up well-worn *Gryphaea nebrascensis* and other pelecypod debris. *Serpula* exhibiting winding burrows up to 2 mm in diameter. Fair to poor intergranular porosity. Lower contact missing.

653.3-655.1 (Rec. 0.0 m)
Core missing.

655.1-655.2 (Rec. 0.1 m)
Mudstone: pale yellowish-brown (10YR6/2), hard, slabby parting, calcareous, minor pyrite, abundant well-worn pelecypod fragments and a few belemnites. Lower contact gradational.

Red Jacket Formation

Burrows Member

Burrows "B"

655.2-656.6 (Rec. 1.4 m)
Sandstone: light olive-grey (5Y6/1), very fine- to fine-grained, clear quartz, subangular to subrounded, moderately sorted, calcite-cemented, slightly to moderately silty, argillaceous, minor pyrite, trace of glauconite, abundance of broken and worn *G. nebrascensis* and other pelecypod shells. Mudstone break between 656.3-656.4 m. Lower two-thirds better sorted. Lower contact missing.

656.6-656.7 (Rec. 0.0 m)
Core Missing.

656.7-657.0 (Rec. 0.3 m)
Sandstone and Mudstone: Interlaminated. Sandstone is light olive-grey (5Y6/1) moderately friable to hard, very fine- to fine-grained clear quartz, subangular to subrounded, well sorted, calcareous over upper half, abundant patches (up to 3 cm across) of pyrite cement, micaceous, abundant small pelecypods (< 1 cm) over upper 10 cm. One large (7 cm across) pelecypod (indeterminate) at lower contact. Mudstone is medium grey (N5), sandy over upper 10 cm becoming increasingly argillaceous and bioturbated over lower 20 cm. Lower contact is sharp and somewhat irregular.

657.0-657.2 (Rec. 0.2 m)
Mudstone: greenish-grey (5GY6/1), slabby parting, weakly calcareous, minor pyrite, abundant small (< 1.5 cm) pelecypods, up to 10 percent very fine- to fine-grained subangular to subrounded floating quartz. Minor micaceous silt laminations near top and base. Lower contact gradational.

657.2-658.0 (Rec. 0.8 m)
Sandstone and Mudstone: Interbedded. Sandstone is very light grey (N8) to dark yellowish-brown (10YR4/2) and mudstone is greenish grey (5GY6/1). Sandstone is very fine- to fine-grained clear quartz, subangular to subrounded, calcite-cemented, minor mica, minor pyrite nodules. Calcareous mudstone component interlaminated with calcite-cemented sandstone. Interbeds of mudstone up to 2 cm thick. Becomes increasingly bioturbated towards base. Sandstone interbeds are oil stained over lower 40 cm. Lower contact is gradational.

658.0-659.0 (Rec. 1.0 m)
Sandstone and Mudstone: Bioturbated, mottled very light grey (N8) sandstone and greenish-grey (5GY6/1) mudstone. Sandstone is very hard, very fine- to fine-grained clear quartz, subangular to subrounded, calcite-cemented, minor mica, minor pyrite, locally abundant oncolites and well-worn pelecypod shell fragments. Mudstone break between 658.3-658.5 m. The interval is highly bioturbated giving it a mottled texture.

Burrows "A"

663.9-666.5 (Rec. 2.6 m)
Claystone: medium grey (N5), hard, slabby parting, weakly calcareous, slightly bentonitic, abundant small (1 cm average) pelecypods (possibly *Pleuromya simplex* and *P. oblongata*?) commonly found in thin (2-3 mm) pavements, minor pyrite (commonly found as nodules). Becomes increasingly interlaminated over lower 40 cm with micaceous, calcite-cemented silt to very fine-grained subangular clear quartz. Moderately burrowed over lower 15 cm. Lower contact is sharp and irregular with the claystone infilling a 1 cm wide crack in the underlying bed.

Moosomin Member

Moosomin "B"

666.5-666.9 (Rec. 0.4 m)
Claystone and Sandstone: Interlaminated greenish-grey (5GY6/1) claystone and very light grey (N8) sandstone. Claystone is hard, calcareous, minor mica and abundant small (1 cm average) pelecypods. Sandstone laminae are slightly micaceous, slightly silty, calcite-cemented very fine- to fine-grained clear quartz.

Moderately bioturbated. Lower contact sharp and irregular.

666.9-667.2 (Rec. 0.3 m)
Mudstone: greenish-grey (5GY6/1), hard, slabby, highly calcareous, trace of mica, few small (<1 cm) pelecypods. Lower contact sharp and irregular.

667.2-668.1 (Rec. 0.9 m)
Sandstone: light greenish-grey (5GY8/1), and greenish-grey (5GY6/1), hard, very fine- to fine-grained clear quartz, subangular to subrounded, well sorted, well-cemented with calcite, slightly argillaceous, trace of mica, trace of pyrite, abundant small (<1 cm) mostly broken-up pelecypods. The interval is intensely bioturbated. Interlaminations of greenish-grey (5GY6/1) mudstone. Lower contact not well preserved but appears sharp.

668.1-668.9 (Rec. 0.8 m)
Mudstone and Sandstone: Interbedded. Mudstone is greenish-grey (5GY6/1) highly calcareous, exhibiting minor mica, minor pyrite, few small (<1 cm average) pelecypods, and locally up to 30 percent floating grains of very fine- to fine-grained subangular clear quartz. Light greenish-grey (5GY8/1) sandstone component is composed of very fine- to fine-grained, subangular to subrounded, clear quartz. It is well-cemented with calcite, slightly silty with minor amounts of mica and pyrite. Between (669.2-669.3 m) sandstone dominates and charophytes occur. The entire interval is moderately to locally intensely bioturbated giving it a mottled texture. Lower contact is gradational.

668.9-670.0 (Rec. 1.1 m)
Sandstone and Mudstone: Interlaminated. Sandstone is light greenish-grey (5GY8/1), hard, composed of very fine- to fine-grained clear quartz, subangular to subrounded, moderately well sorted, silty, slightly argillaceous, calcite-cemented, minor mica, minor to locally abundant pyrite, few poorly preserved small (<1 cm) pelecypods. Greenish-grey (5GY6/1) mudstone interlaminations are calcareous with minor pyrite and up to 10 percent floating very fine- to fine-grained quartz. The entire interval is moderately bioturbated. Lower contact gradational.

670.0-670.6 (Rec. 0.6 m)
Claystone: greenish-grey (5GY6/1), hard, slabby parting, calcareous, minor pyrite, trace of indeterminate fish? bone fragments. Lower contact sharp.

670.6-671.0 (Rec. 0.4 m)
Sandstone: yellowish-grey (5Y8/1) to light greenish-grey (5GY8/1), hard, very fine- to fine-grained clear quartz, subangular to subrounded, moderately argillaceous, silty, minor mica, trace of pyrite, sparse interlaminations of sandy mudstone. The interval is slightly to moderately bioturbated. Lower contact sharp.

671.0-672.4 (Rec. 1.4 m)
Sandstone: yellowish-grey (5Y8/1) to light greenish-grey (5GY8/1) and pale yellowish-brown (10YR6/2), moderately friable to friable, very fine- to fine-grained clear quartz, subangular to subrounded, calcareous, slightly to moderately argillaceous, silty to locally very silty, minor mica, trace of pyrite. Highly interlaminated with silty, micaceous, moderately to highly argillaceous sandy laminations. Becomes increasingly silty towards base. Pale yellowish-brown (10YR6/2) oil-stained patches within numerous intervals of less argillaceous and calcite-cemented sandstone.

MAPS NOT FILMED

CARTES OMISES